NASA Technical Memorandum 81946

NASA-TM-81946 19810012139

1980 DIRECT STRIKE LIGHTNING DATA

FELIX L. PITTS AND MITCHEL E. THOMAS

FEBRUARY 1981

NASA
National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

1980 DIRECT STRIKE LIGHTNING DATA

Felix L. Pitts and Mitchel E. Thomas

SUMMARY

This report presents the results obtained during the 1980 direct-strike lightning tests of the NASA Langley Research Center lightning-instrumented F-106B aircraft. The tests were conducted in the vicinity of the National Severe Storms Laboratory, Norman, Oklahoma, and in the vicinity of the NASA Langley Research Center, Hampton, Virginia. The entire strike data obtained for 10 strikes in the 1980 campaign are presented in this report.

SYMBOLS

$\dot{B}$	rate of change of magnetic flux density, tesla per second
$\dot{D}$	rate of change of electric flux density, ampere per square meter
$\dot{I}$	rate of change of current, ampere per second
A/m^2	ampere per square meter
m	meter
T/s	tesla per second
A/s	ampere per second
P-P	peak-to-peak

INTRODUCTION

This report presents the direct-strike lightning data obtained in 1980 during lightning flight tests of the NASA Langley Research Center lightning-instrumented F-106B aircraft. There were 10 strikes to the aircraft during

this campaign; representative initial strike data waveforms which were reported in reference 1 are included here for completeness. The instrumentation system and sensors are described in references 2, 3, and 4; a summary overview of the instrumentation system and 1980 campaign is presented in reference 5.

Lightning Data

The 1980 campaign resulted in 10 direct strikes to the aircraft from 19 storm penetration flights. Table I summarizes the data recorded and particulars concerning data acquisition. The entries under the D-dot FWD and B-dot LONG (abbreviated $\dot{D}_F$ and $\dot{B}_L$ in the figures)are the number of 1310 microsecond records acquired during strikes from the D-dot forward and B-dot longitudinal sensors at 10-nanosecond sample intervals. The five entries under the I-dot column represent the number of discrete strike events recorded from the I-dot sensor on the 6-MHz analog video tape recorder. There was an instrumentation system malfunction on flight 80-029 which invalidated the three B-dot entries for that flight. The sign convention for polarity resolution of the measured fields and currents is such that an increasing electric field vector from the aircraft is positive, and increasing current from forward to aft is positive and results in a positive magnetic field measurement.

Table II lists the characteristics of the instrumentation system as initially configured for the flight tests. The full-scale ranges of the recording system were chosen to accommodate submicrosecond rise time lightning characteristics: specifically, electric field changes of 500 kV in 0.1 microsecond and current changes of 10 kA in 0.1 microsecond. The initial strikes obtained during flights 80-018 and 80-019 were noteworthy in that the electric characteristics (D-dot) spanned 60 percent of full scale, whereas the magnetic characteristics (B-dot, I-dot) did not exceed the thresholds shown in table II. Subsequently, the

gain of the B-dot and I-dot data channels was increased by one and two orders of magnitude, respectively. Also, the trigger thresholds of the transient recorders were reduced to 15 percent from 20 percent of full scale, as shown in table III which summarizes the configuration for flights 80-023 through 80-038. Both the electric and magnetic characteristics were recorded during subsequent strikes as noted in table I.

The detailed data waveforms presented are preceded by overview figures which depict the chronology of the transient recorder memory for the direct strikes. Figures 1 through 8 are the overview figures and figures 9 through 31 are the data waveforms obtained in the 1980 flight tests. The locations of the sensors and lightning attachment points and paths are shown in figures 32 through 36. Table IV summarizes the flight data obtained and identifies the simultaneously recorded data. Record numbers enable correlation of simultaneously recorded D-dot, B-dot, and I-dot data waveforms with overview figures as shown in table IV where multiple checks for a given flight and record number indicate simultaneously recorded data as in flights 80-036 and 80-038.

As was shown in table I, the D-dot and B-dot data were recorded by independent digital transient recorders and the I-dot data was recorded on a separate, continuously recording wideband analog recorder. The time resolution capability of the instrumentation system between the digital transient recorders and the analog recorder was about 1 millisecond. This required that the simultaneity of the I-dot data (with B-dot and D-dot) be deduced by the absence of other transients on the I-dot analog tape around the strike time. (Strike time was determined from pilot notes and trigger event discretes recorded from the transient recorders.) Detailed I-dot waveforms, which were recorded on the wideband analog recorder, are shown in the figures with an elapsed time scale which refers only to elapsed time during the strike event, whereas the time scales for the data obtained using the transient recorders refer to the total 1310 microsecond memory length.

REFERENCES

1. Pitts, Felix L.; and Thomas, Mitchel E.: Initial Direct Strike Lightning Data. NASA TM 81867, August 1980.

2. Pitts, Felix L., et al.: Inflight Lightning Characteristics Measurement System. Report No. FAA-RD-79-6. Federal Aviation Administration - Florida Institute of Technology Workshop on Grounding Technology, Melbourne, Fla., March 6-8, 1979, pp. 105-111.

3. Thomas, Robert M., Jr.: Expanded Interleaved Solid-State Memory for a Wide Bandwidth Transient Waveform Recorder. NASA CP-2128, FAA-RD-8-30. Lightning Technology, NASA Langley Research Center, April 22-24, 1980. p. 119.

4. Trost, Thomas F.; and Zaepfel, Klaus P.: Broadband Electromagnetic Sensors for Aircraft Lightning Research. op. cit., p. 131.

5. Pitts, Felix L.: Electromagnetic Measurement of Lightning Strikes to Aircraft. AIAA 19th Aerospace Sciences Meeting, St. Louis, Mo., Jan. 1981. AIAA-81-0083.

TABLE I - 1980 DIRECT STRIKE DATA SUMMARY

DATE	FLIGHT NO.	NO. STRIKES (COMMENTS)	$\dot{D}$ FWD (A)	$\dot{B}$ LONG (A)	$\dot{I}$ (B)	$\dot{D}$ R. WING (B)
6-17	80-018	1 (BOOM)	1	0	0	0
	80-019	2 (BOOM)	1	0 *	0 **	0
7-22	80-023	0 (NEARBY)	3	1	***	0
8-12	80-029	1 (CANOPY)	1	3	***	0
8-15	80-030	0	0	1	***	0
9-1	80-036	1 (NOSE)	1	1	***	0
9-3	80-038	5 (BOOM)	3	4	5	0

(A) EXPANDED BIOMATION DIGITAL TRANSIENT RECORDER 10 ns/SAMPLE
(B) RCA ADVISER 62 6-MHz B.W. ANALOG RECORDER (100 ns STEP RESPONSE)
* X 10 GAIN CHANGE ** X 100 GAIN CHANGE
*** BOOM NOT INVOLVED DATA NOT EXPECTED

TABLE II - MEASUREMENT CONFIGURATION FOR FLIGHTS 80-018 and 80-019

SENSOR	RECORDER	SAMPLE RATE (BANDWIDTH)	P-P FULL SCALE	THRESHOLD
D-Dot Forward	Transient	100 MHz (50* MHz)	± 24.5 A/m^2	+4.9 A/m^2
B-Dot Longitudinal	Transient	100 MHz (50* MHz)	± 8695 T/s	+1739 T/s
D-Dot Right Wing	Wideband Analog	(6 MHz)	± 28 A/m^2	± 2.8 A/m^2
I-Dot	Wideband Analog	(6MHz)	$\pm 4.7 \times 10^{10}$ A/s	$\pm 4.7 \times 10^{9}$ A/s

*Four-pole linear phase low-pass filter 3 dB point at 50 MHz.

TABLE III - MEASUREMENT CONFIGURATION FOR FLIGHTS 80-023 THROUGH 80-038

SENSOR	RECORDER	SAMPLE RATE (BANDWIDTH)	P-P FULL SCALE	THRESHOLD
D-Dot Forward	Transient	100 MHz (50* MHz)	± 24.5 A/m^2	+3.7 A/m^2
B-Dot Longitudinal	Transient	100 MHz (50* MHz)	± 870 T/s	+130 T/s
D-Dot Right Wing	Wideband Analog	(6 MHz)	± 28 A/m^2	± 2.8 A/m^2
I-Dot	Wideband Analog	(6 MHz)	$\pm 4.7 \times 10^{8}$ A/s	$\pm 4.7 \times 10^{7}$ A/s

*Four-pole linear phase low-pass filter 3 dB point at 50 MHz.

TABLE IV - SUMMARY OF SIMULTANEOUS DIRECT STRIKE WAVEFORMS

FLIGHT	Record 1			Record 2			Record 3			Record 4			Record 5		
	$\dot{D}$	$\dot{B}$	$\dot{I}$	$\dot{D}$	$\dot{B}$	$\dot{I}$	$\dot{D}$	$\dot{B}$	$\dot{I}$	$\dot{D}$	$\dot{B}$	$\dot{I}$	$\dot{D}$	$\dot{B}$	$\dot{I}$
80-018	✓														
80-019	✓														
80-023		✓		✓			✓			✓					
80-029	✓														
80-030		✓													
80-036	✓	✓													
80-038		✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓

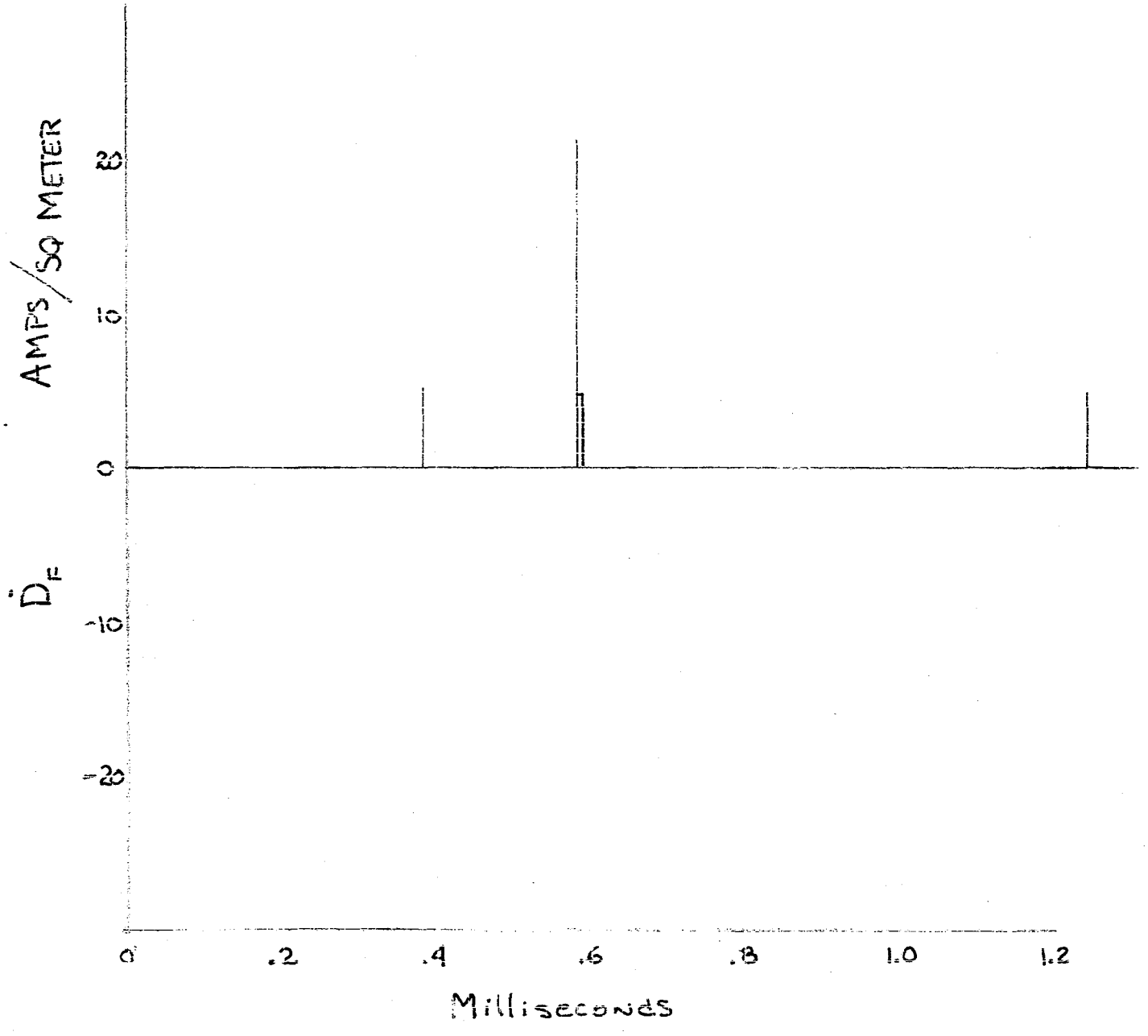

Figure 1. - Overview of $\dot{D}_F$ for flight 80-018.

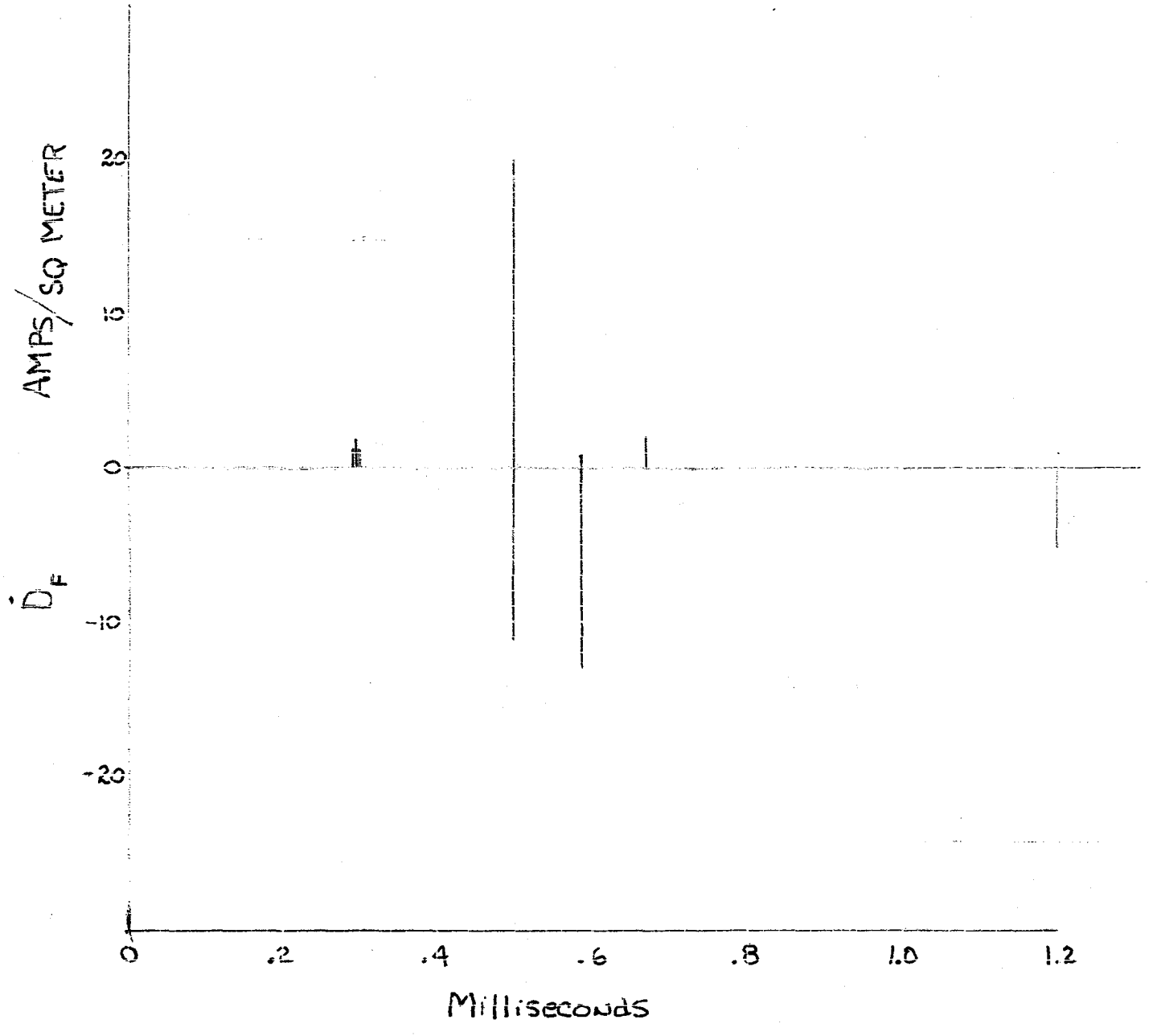

Figure 2. - Overview of $\dot{D}_F$ for flight 80-019.

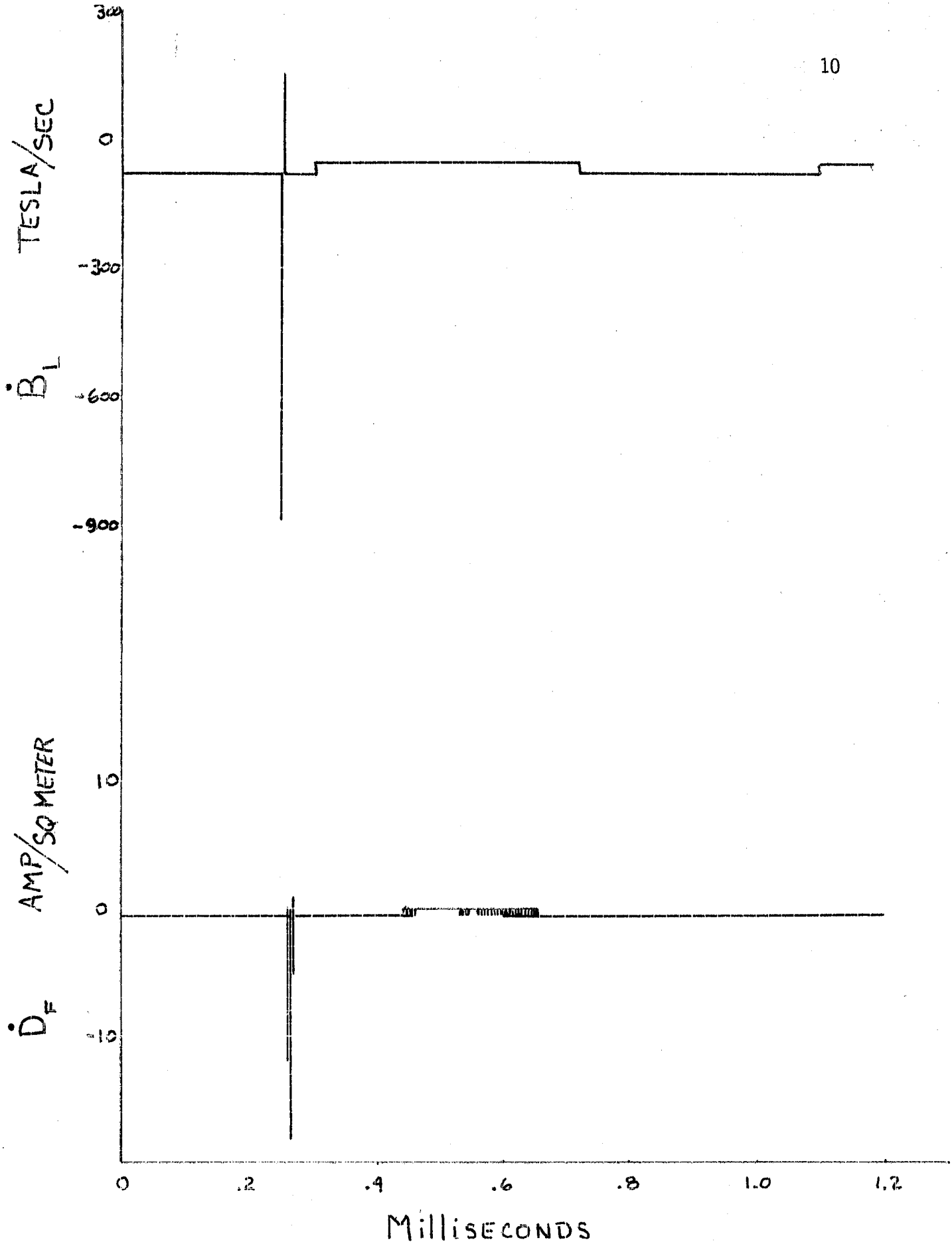

Figure 3. - Overview of simultaneous $\dot{B}_L$ and $\dot{D}_F$ for flight 80-036.

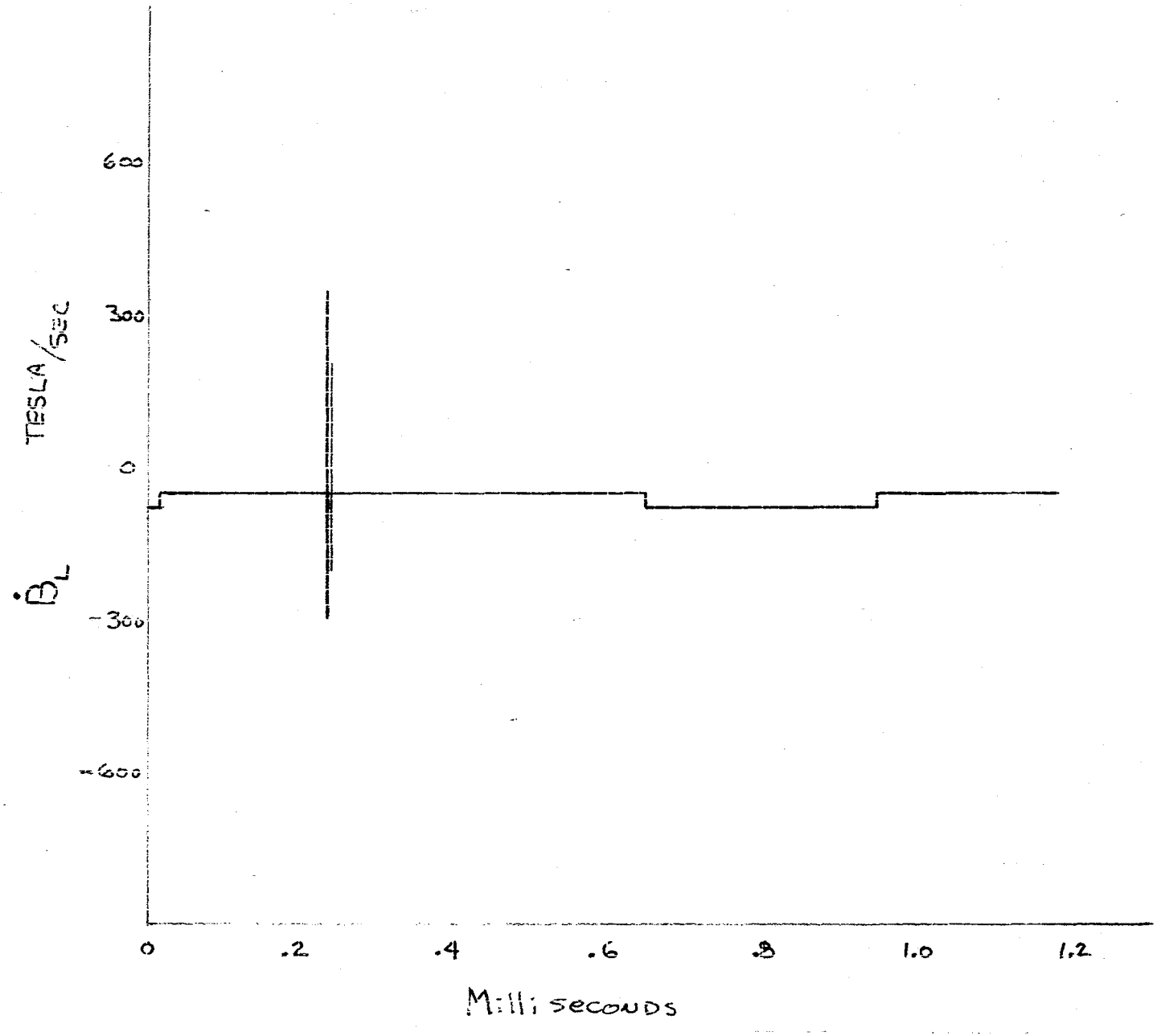

Figure 4. - Overview of $\dot{B}_L$ for flight 80-038, record 1.

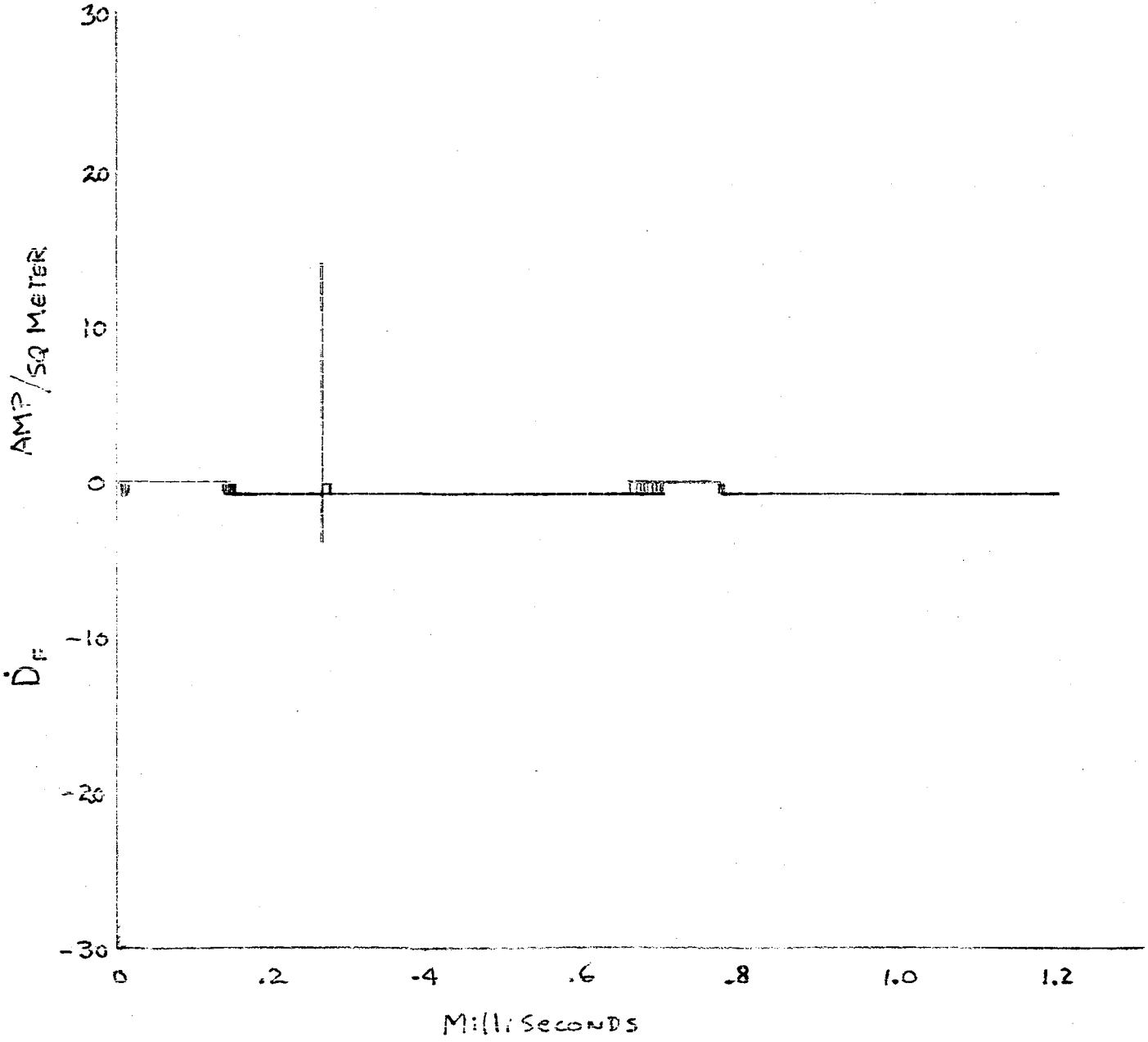

Figure 5. - Overview of $\dot{D}_F$ for flight 80-038, record 2.

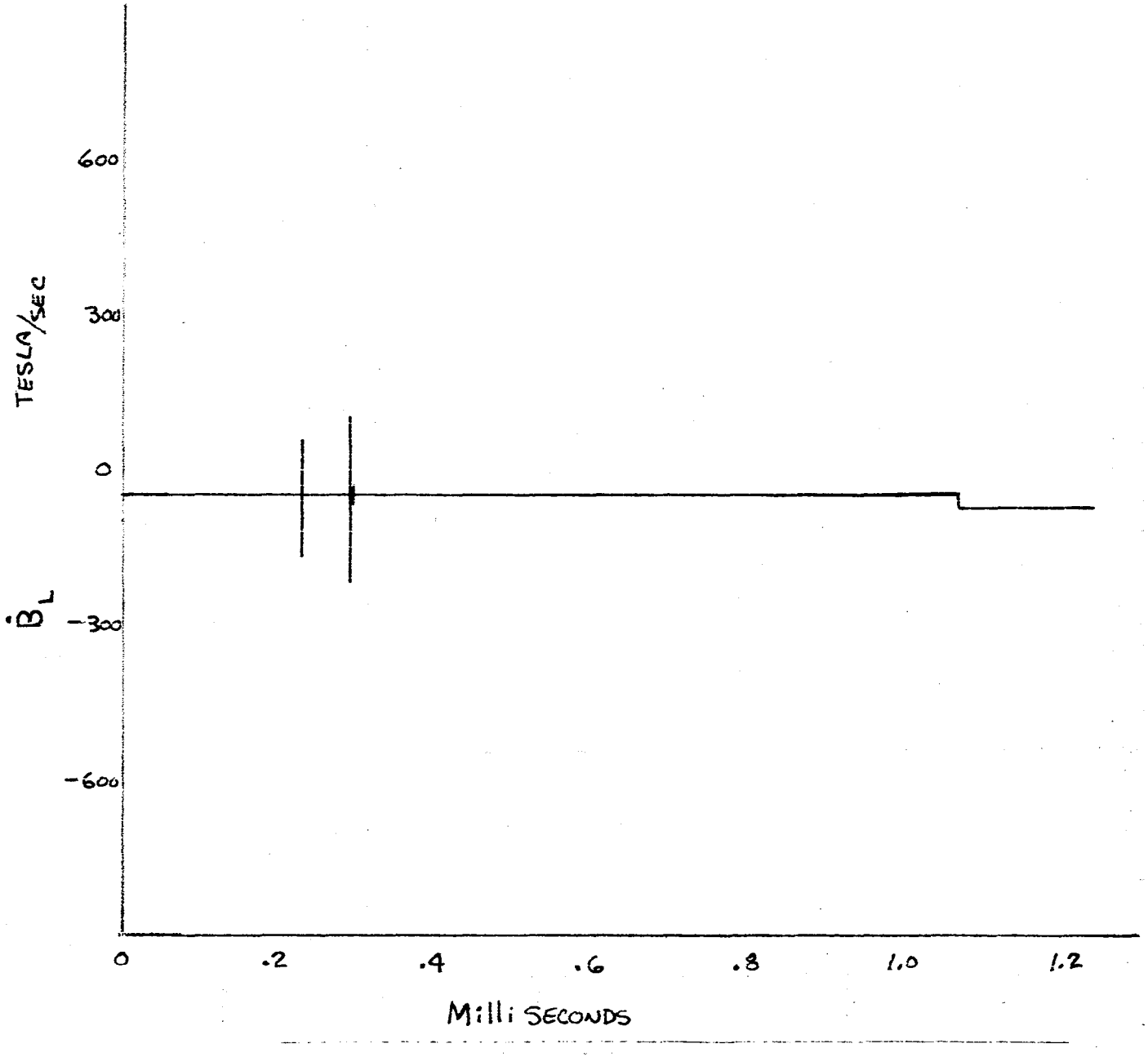

Figure 6. - Overview of $\dot{B}_L$ for flight 80-038, record 3.

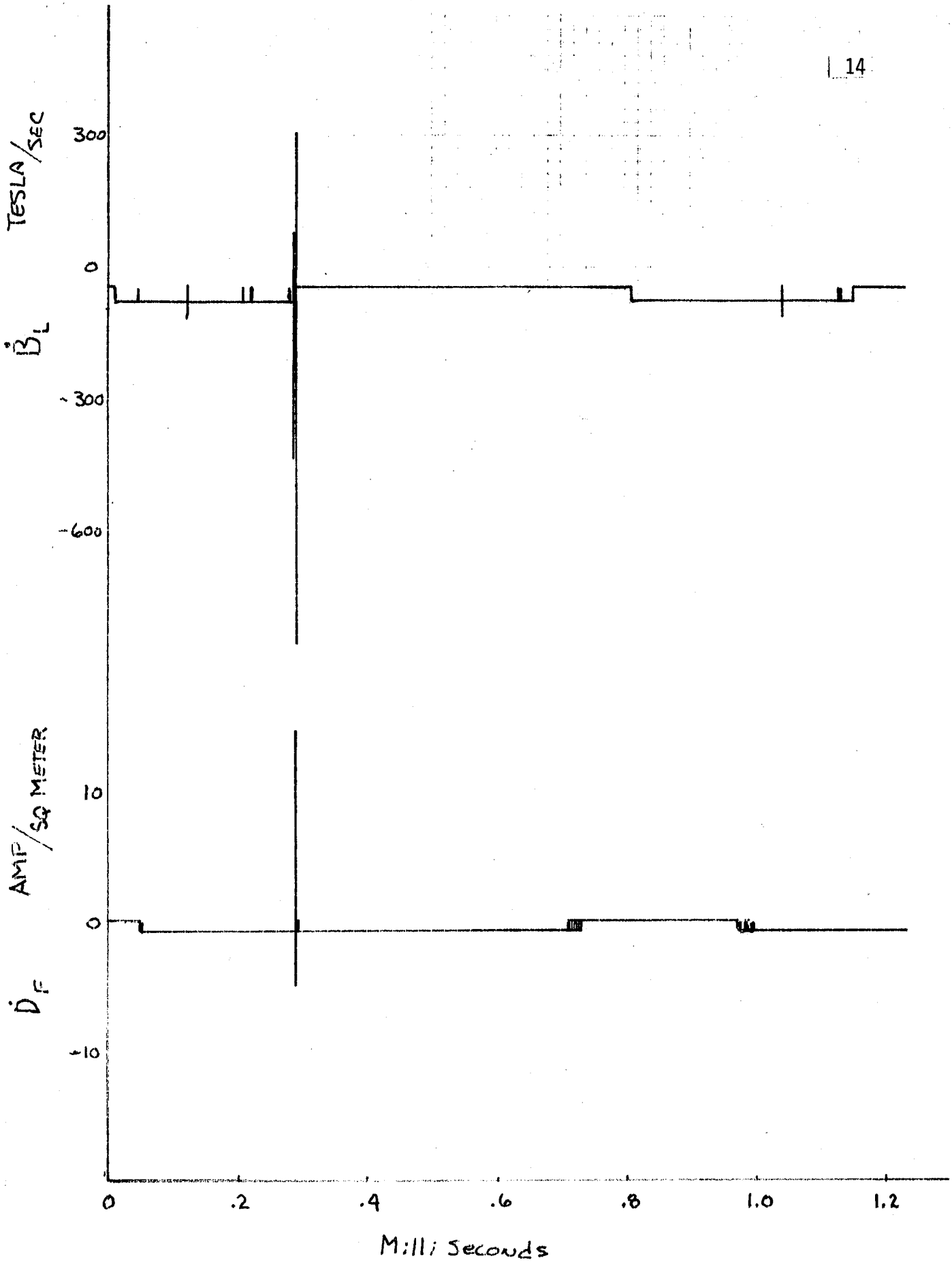

Figure 7. - Overview of simultaneous $\dot{B}_L$ and $\dot{D}_F$ for flight 80-038, record 4.

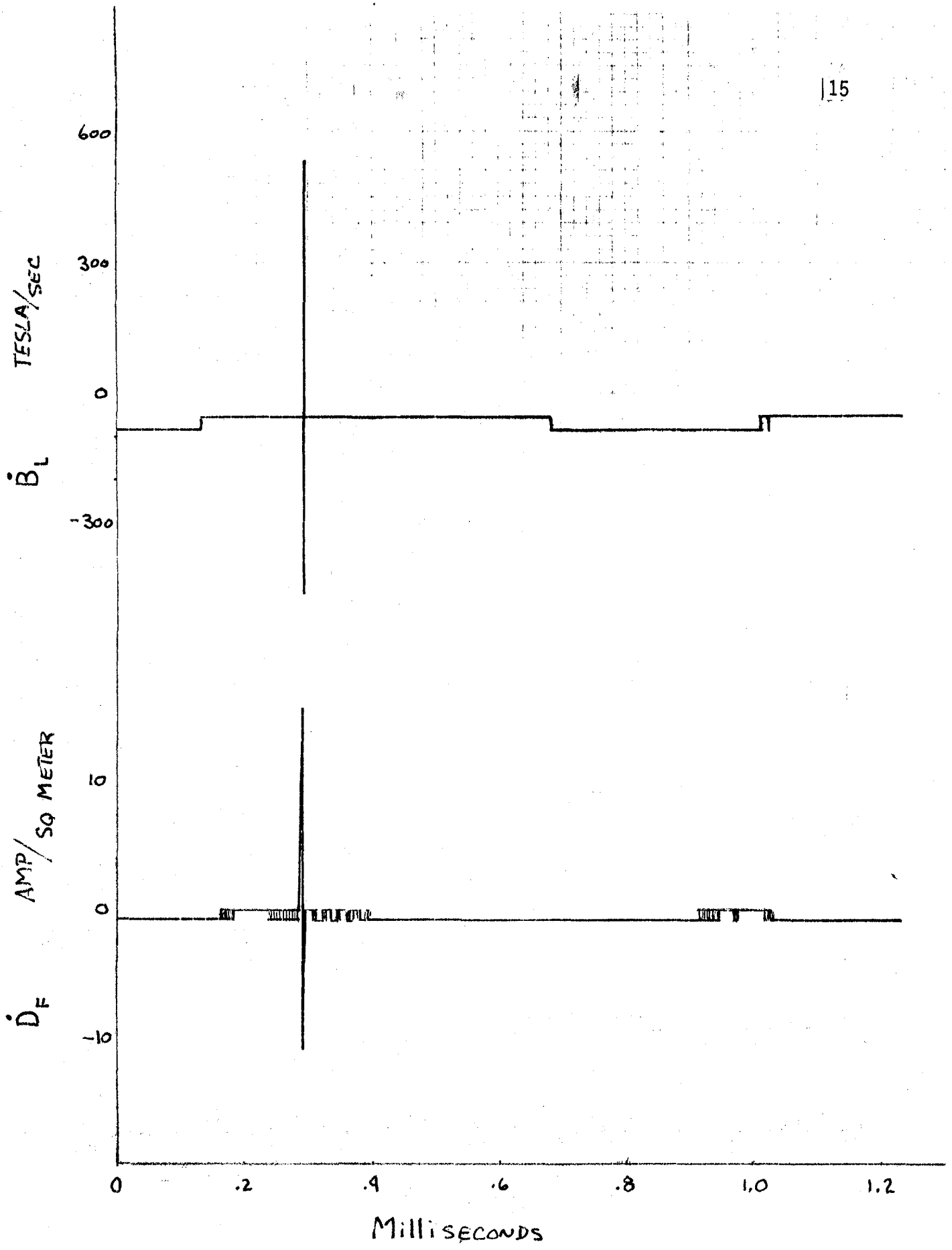

Figure 8. - Overview of simultaneous $\dot{B}_L$ and $\dot{D}_F$ for flight 80-038, record 5.

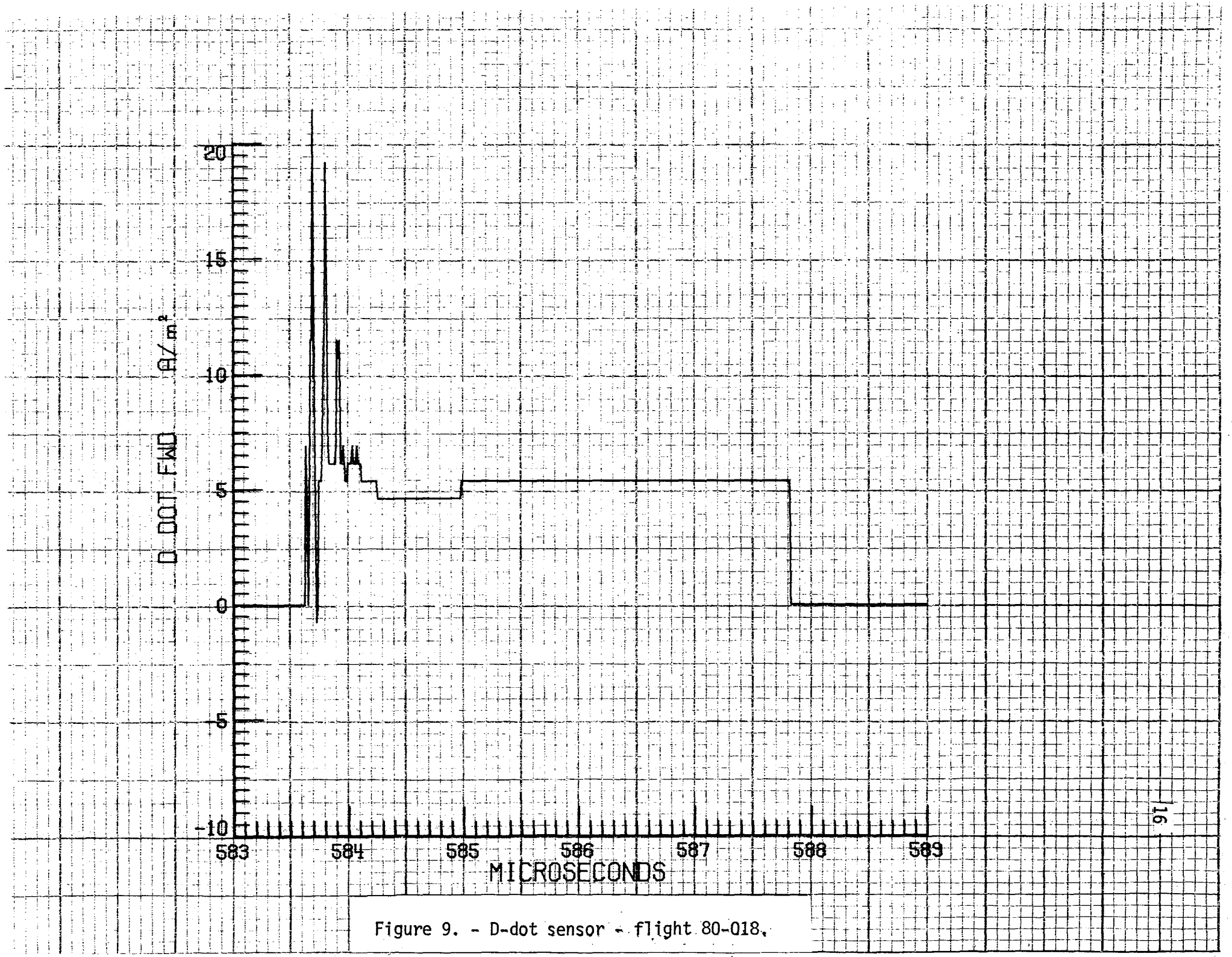

Figure 9. - D-dot sensor - flight 80-018.

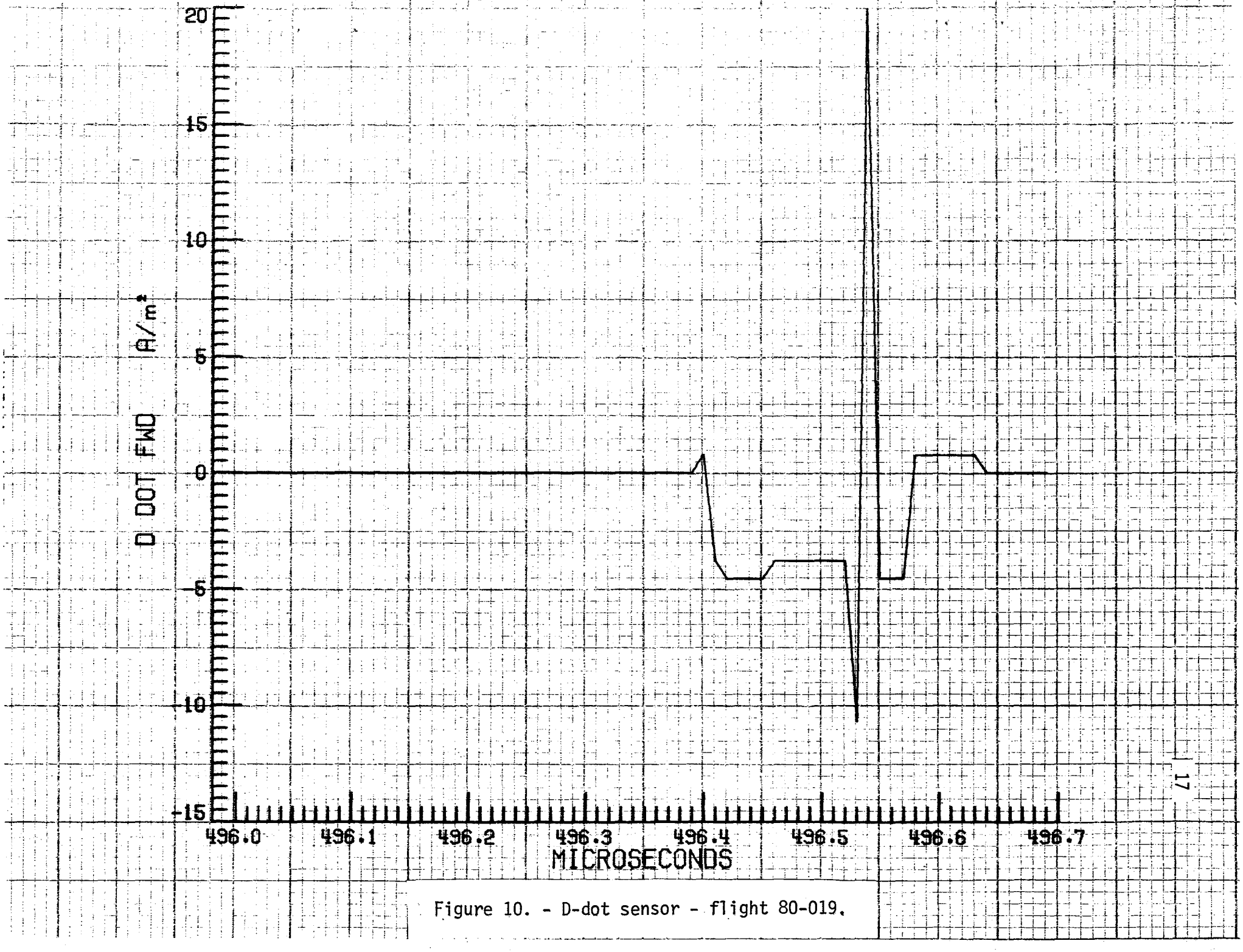

Figure 10. - D-dot sensor - flight 80-019.

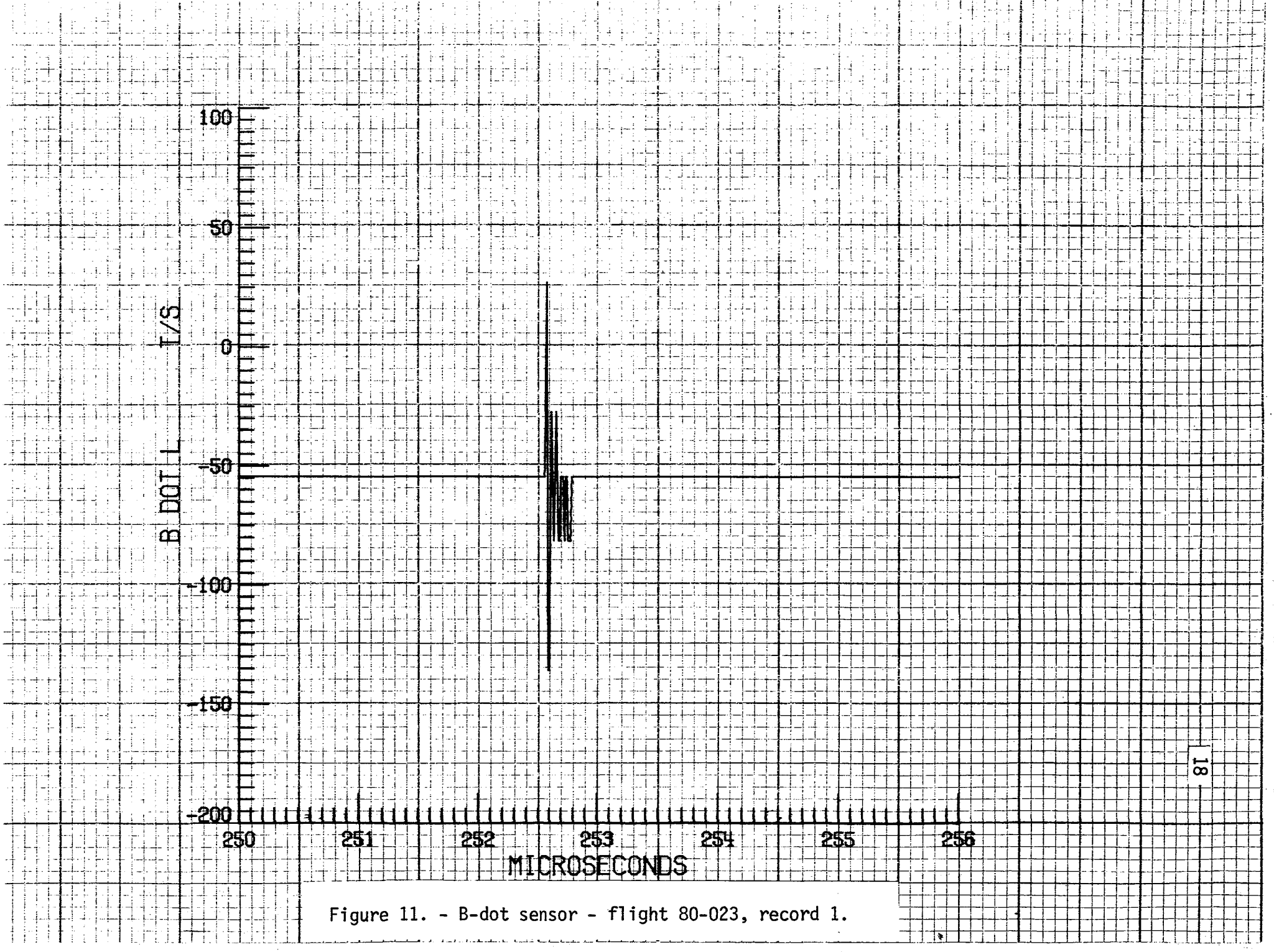

Figure 11. - B-dot sensor - flight 80-023, record 1.

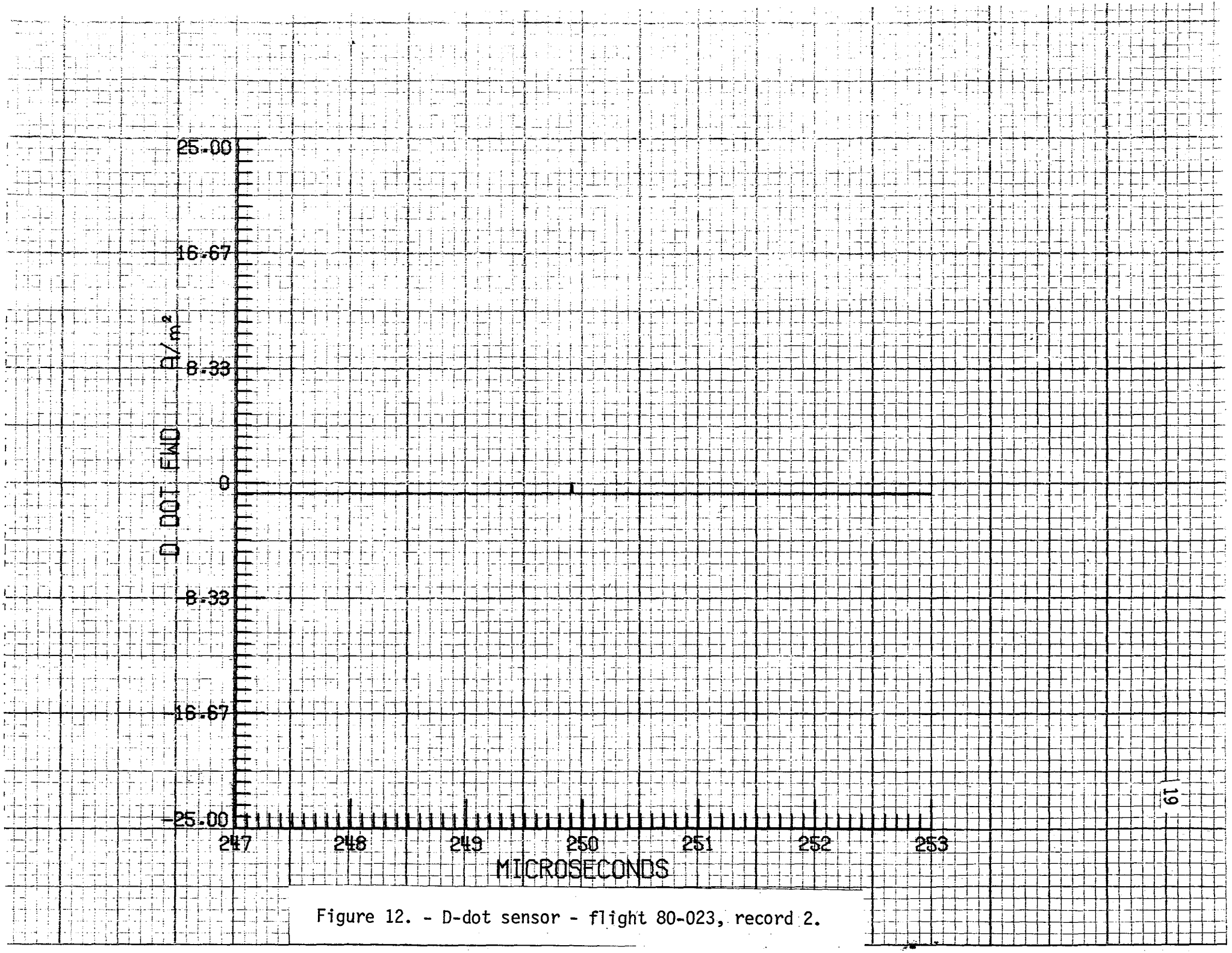

Figure 12. - D-dot sensor - flight 80-023, record 2.

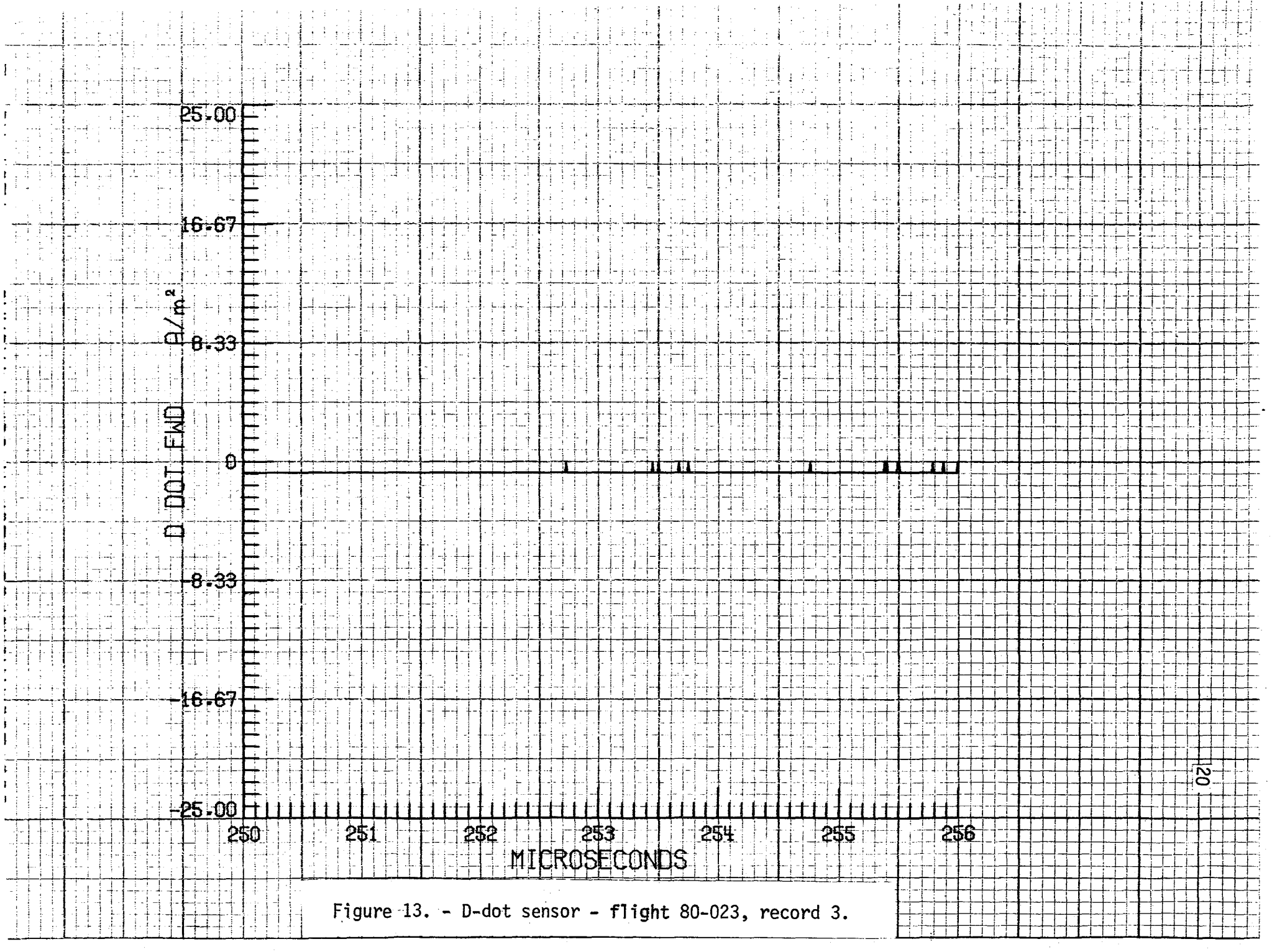

Figure 13. - D-dot sensor - flight 80-023, record 3.

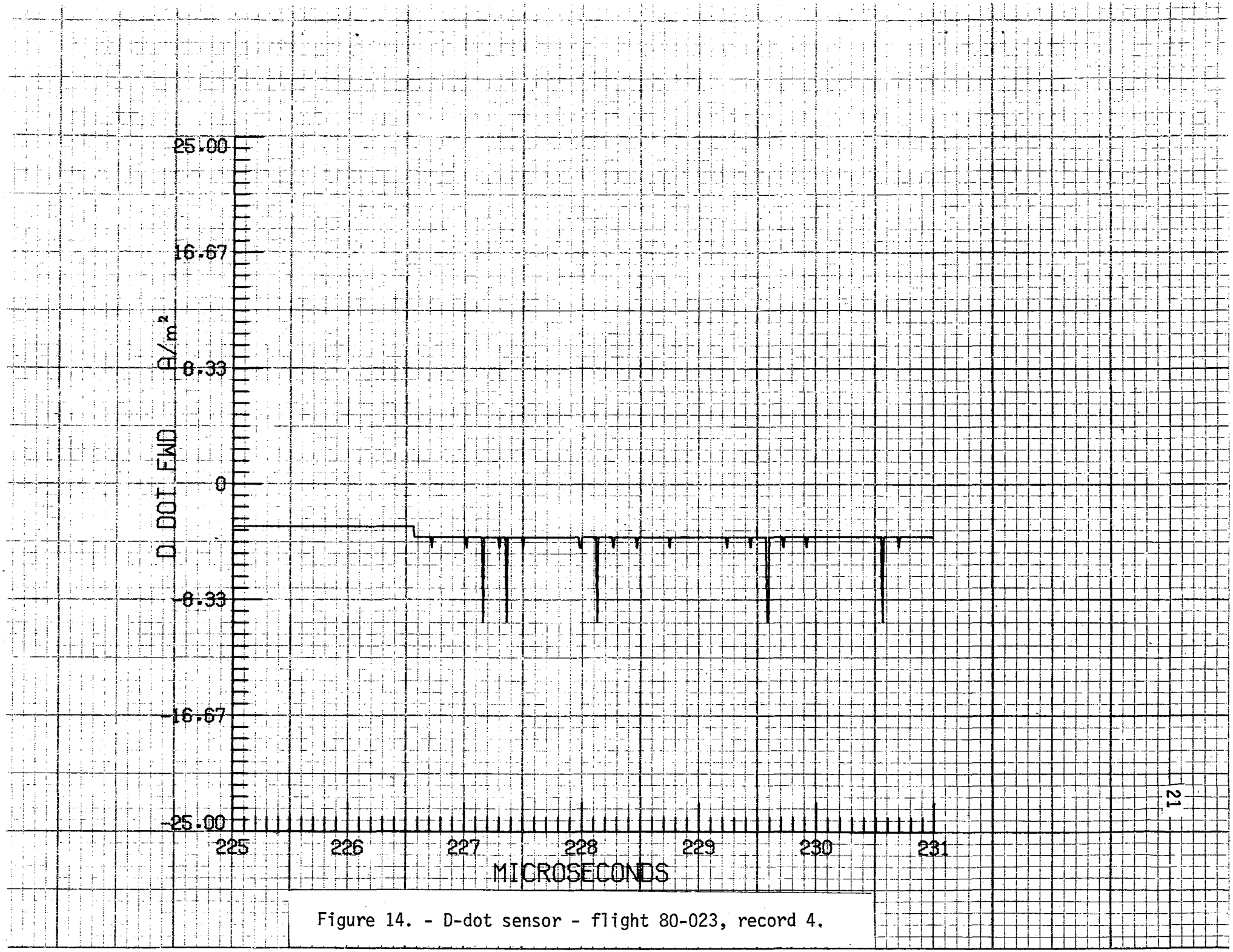

Figure 14. - D-dot sensor - flight 80-023, record 4.

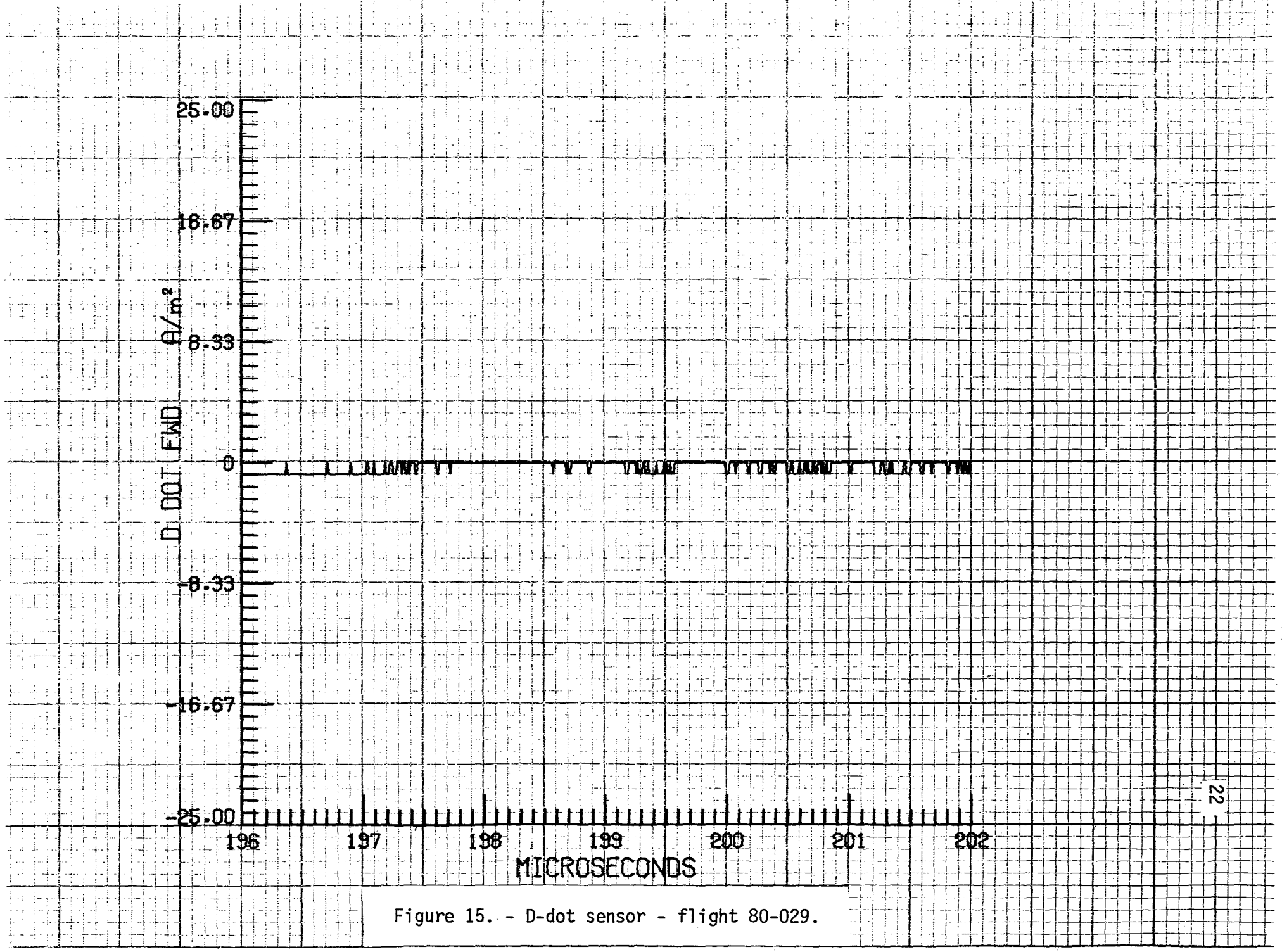

Figure 15. - D-dot sensor - flight 80-029.

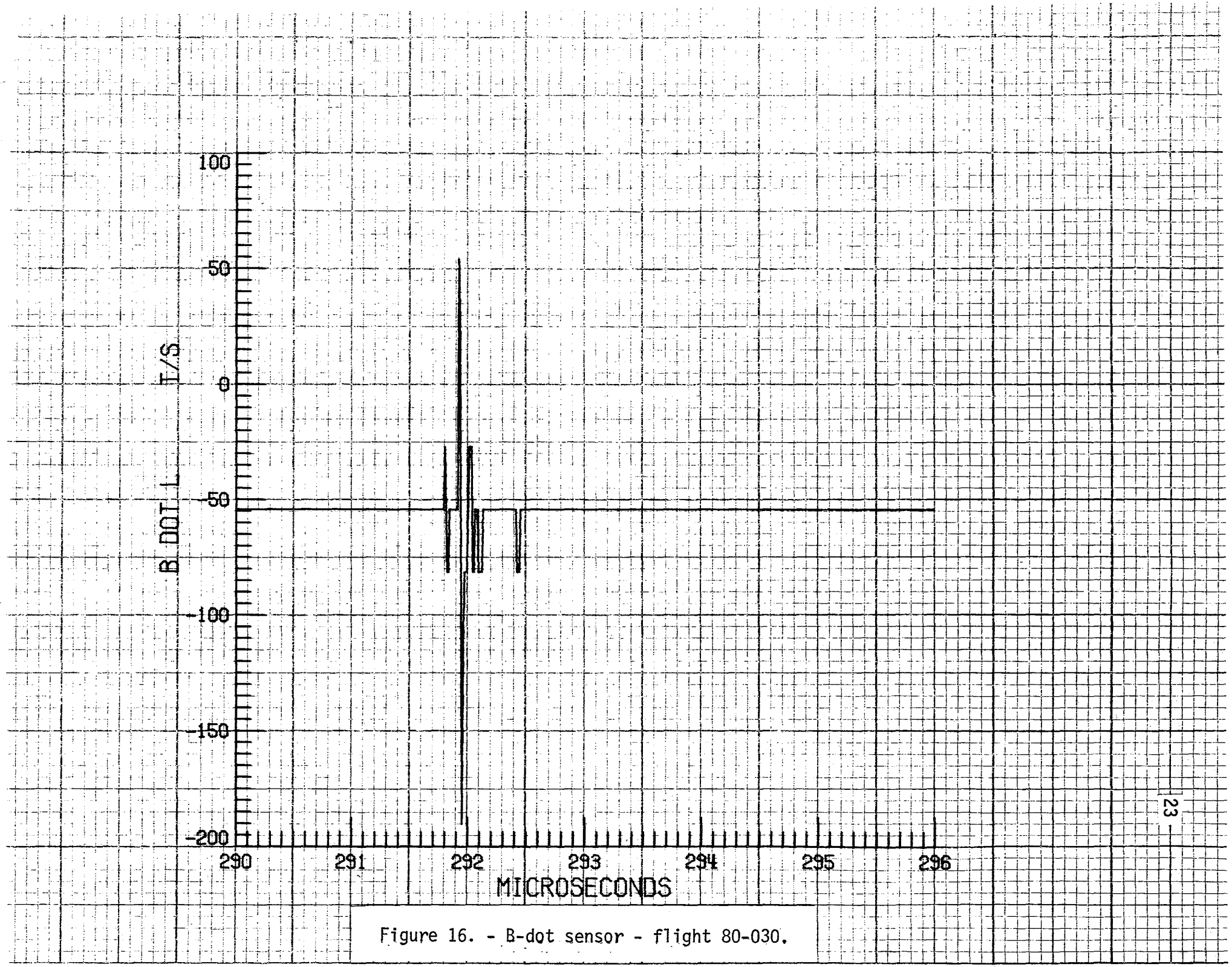

Figure 16. - B-dot sensor - flight 80-030.

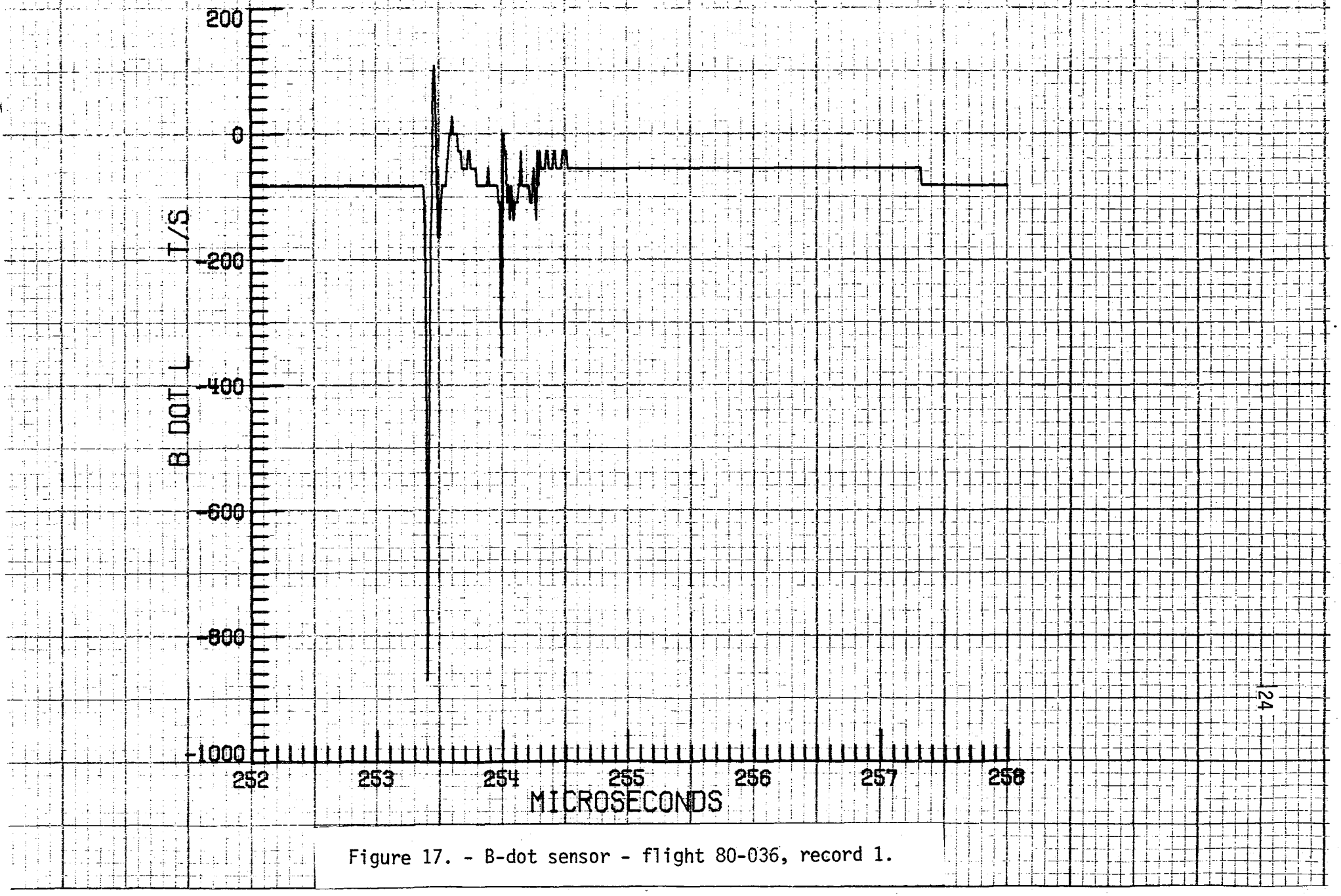

Figure 17. - B-dot sensor - flight 80-036, record 1.

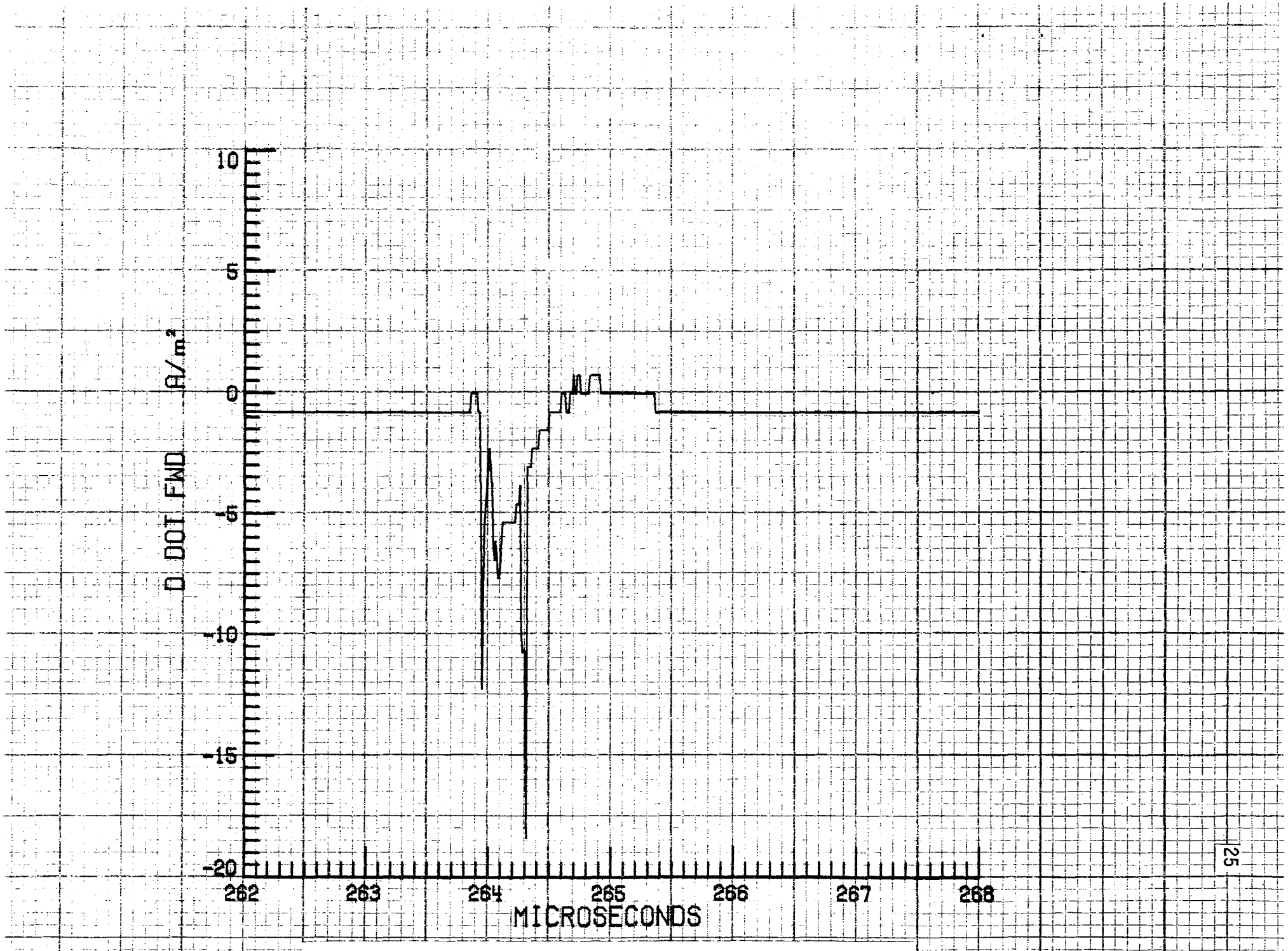

Figure 18. - D-dot sensor - flight 80-036, record 1.

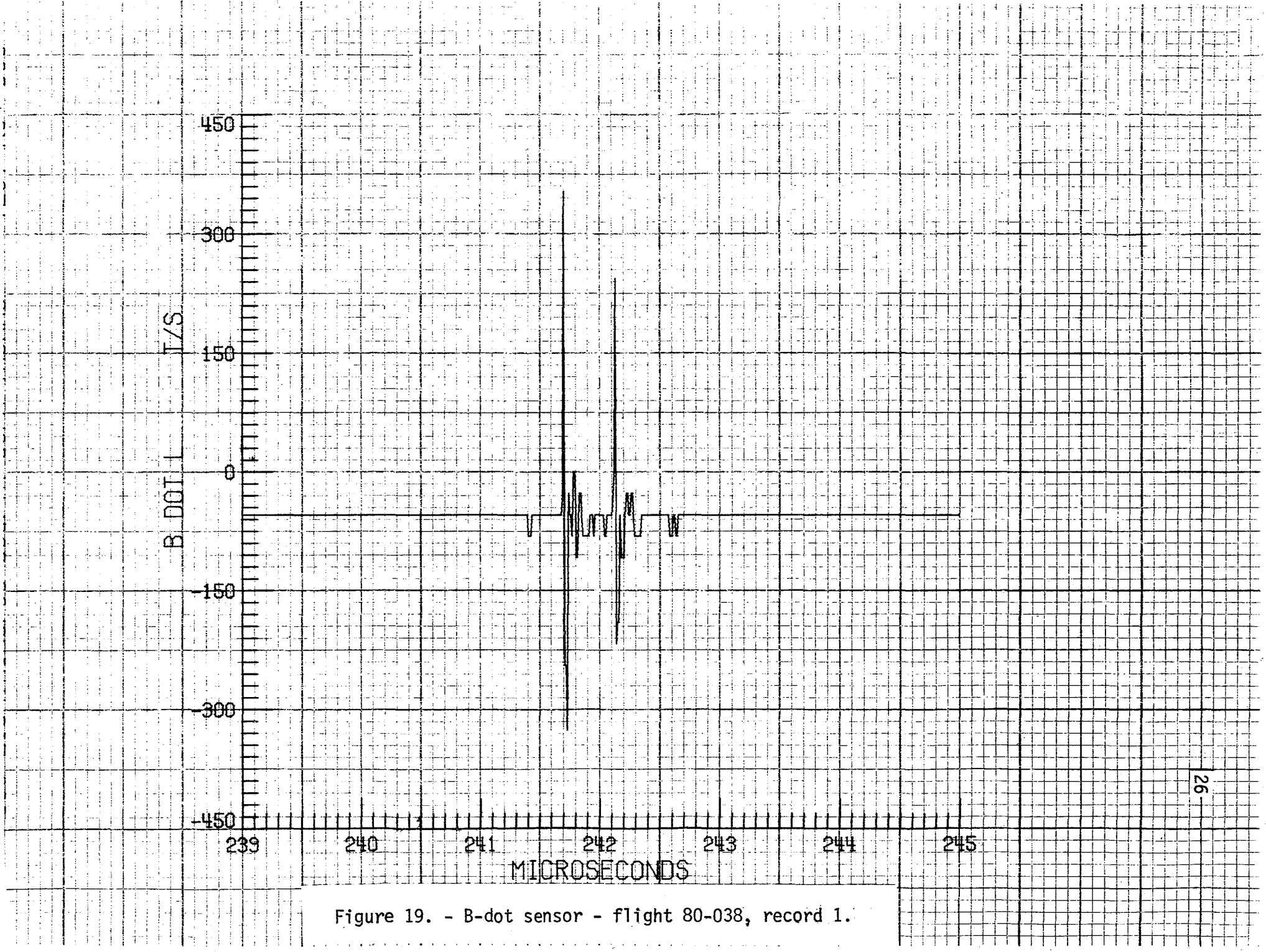

Figure 19. - B-dot sensor - flight 80-038, record 1.

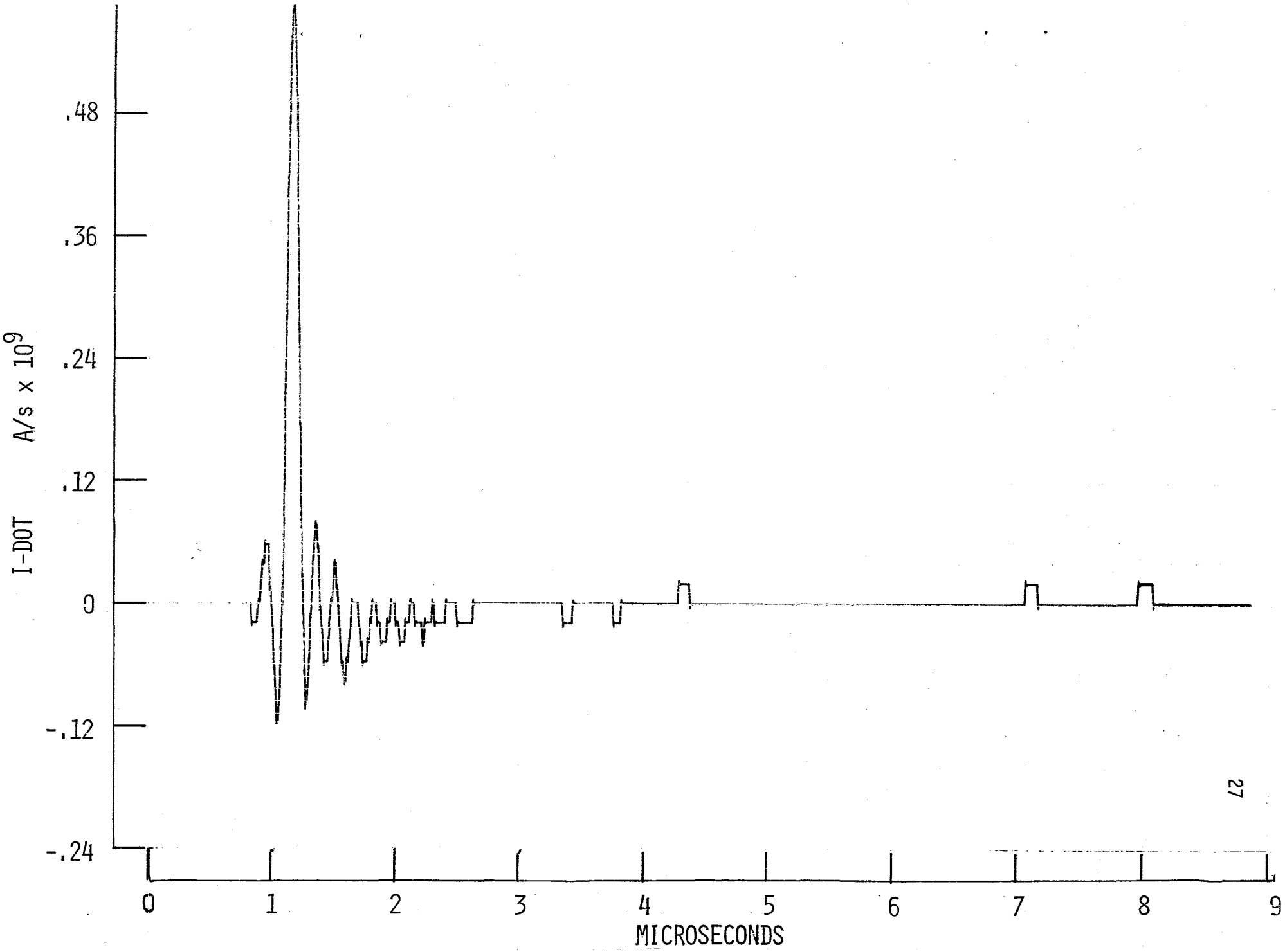

Figure 20. - I-dot sensor - flight 80-038, record 1.

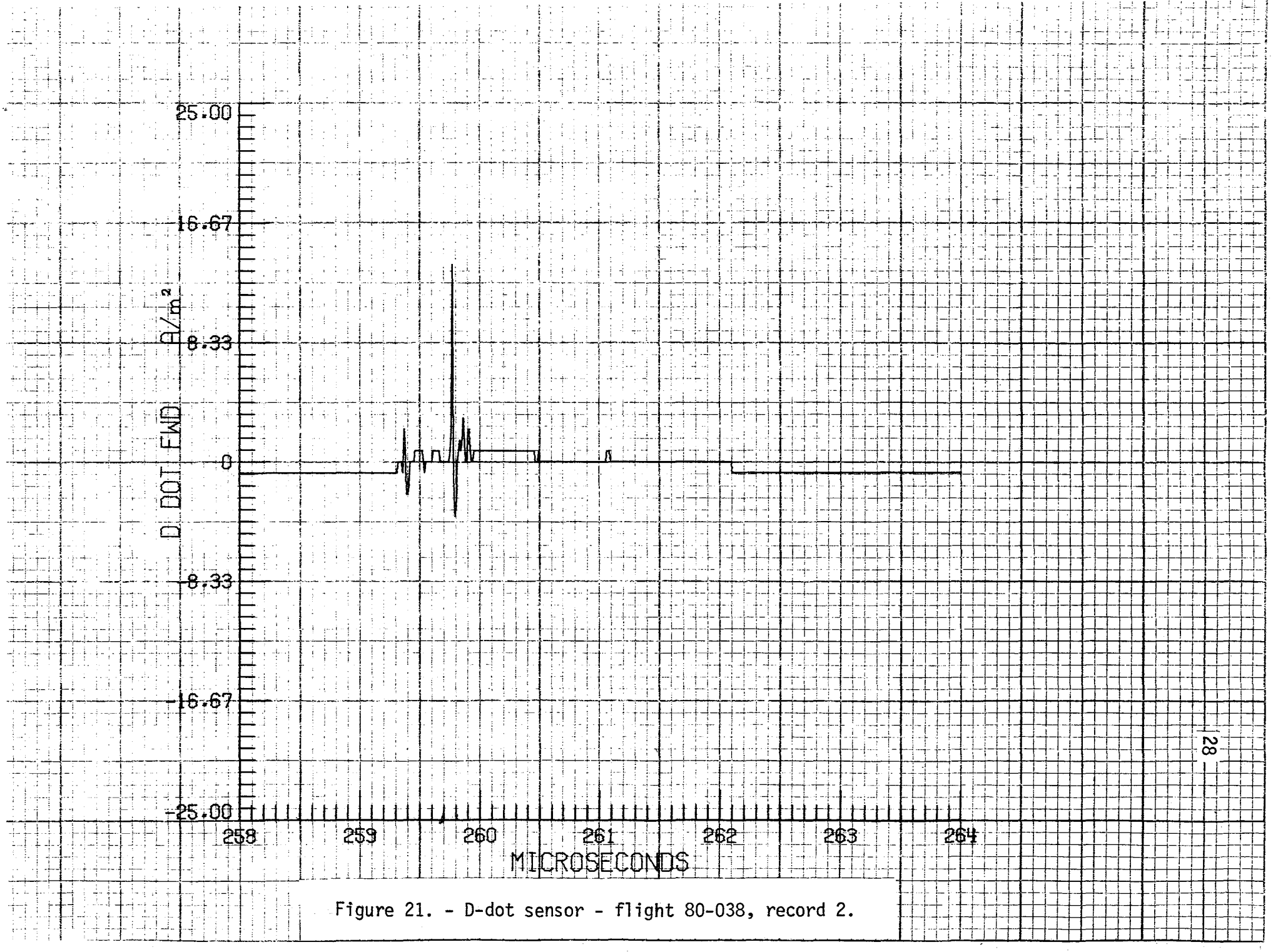

Figure 21. - D-dot sensor - flight 80-038, record 2.

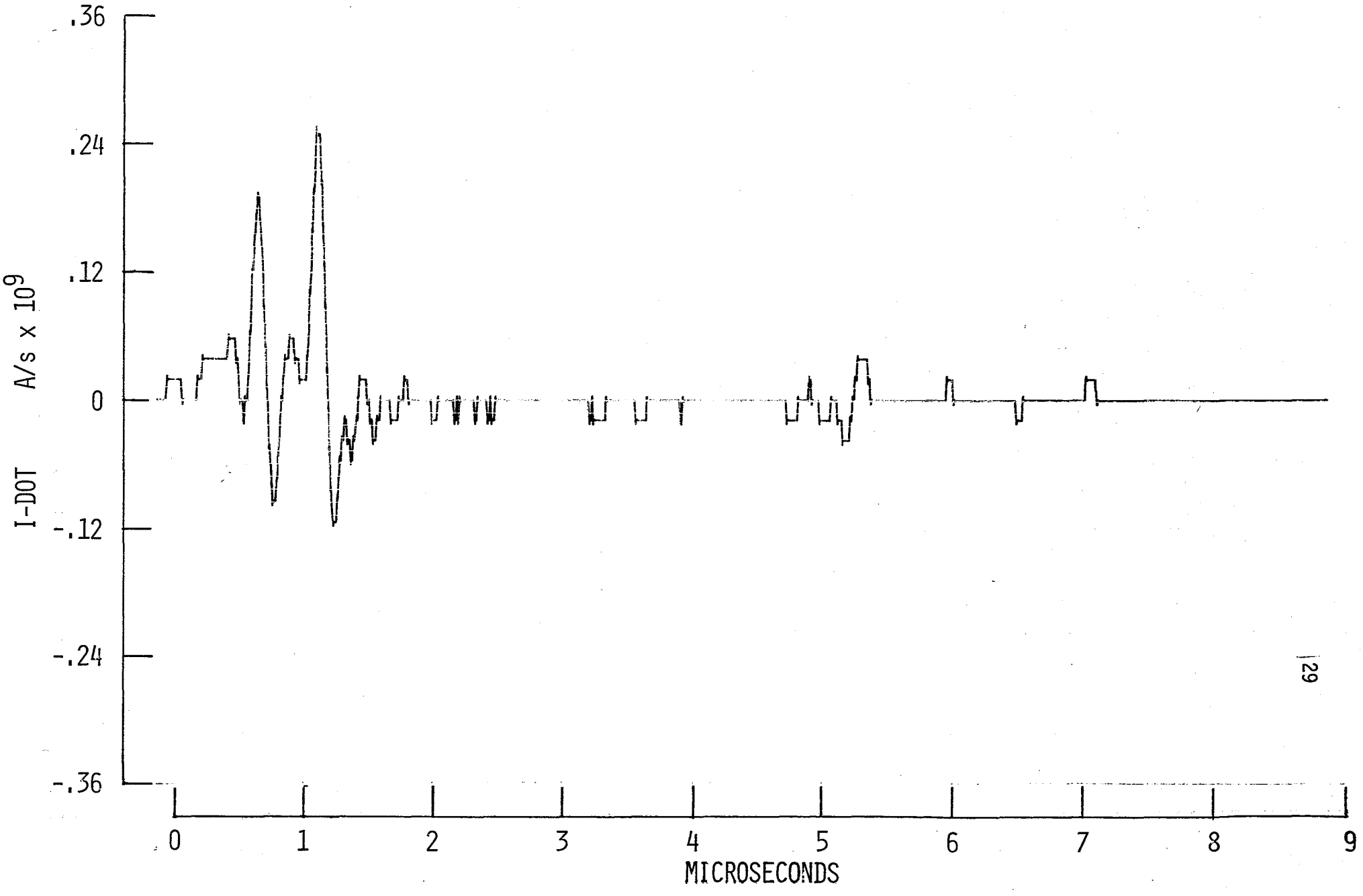

Figure 22. - I-dot sensor - flight 80-038, record 2.

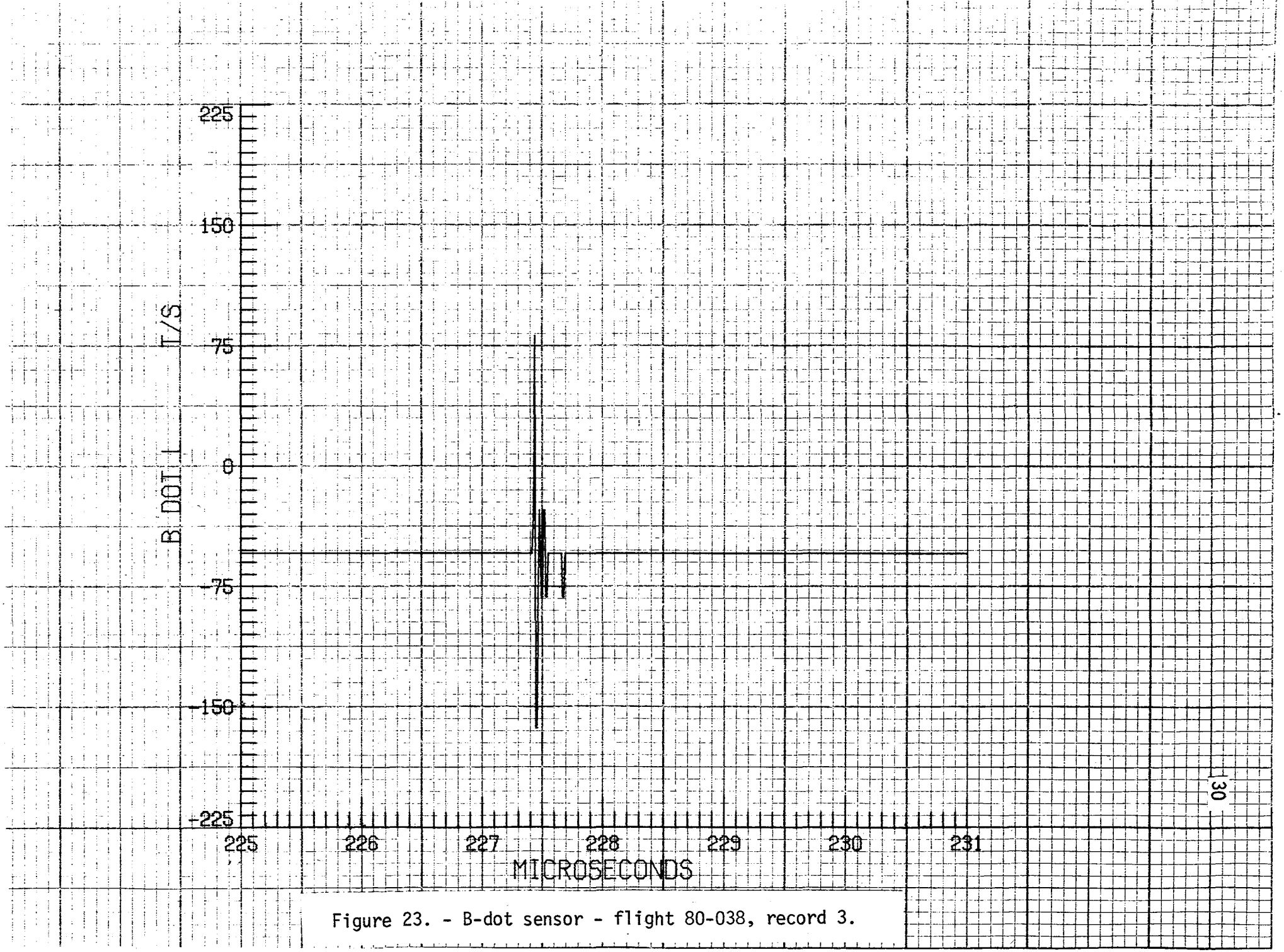

Figure 23. - B-dot sensor - flight 80-038, record 3.

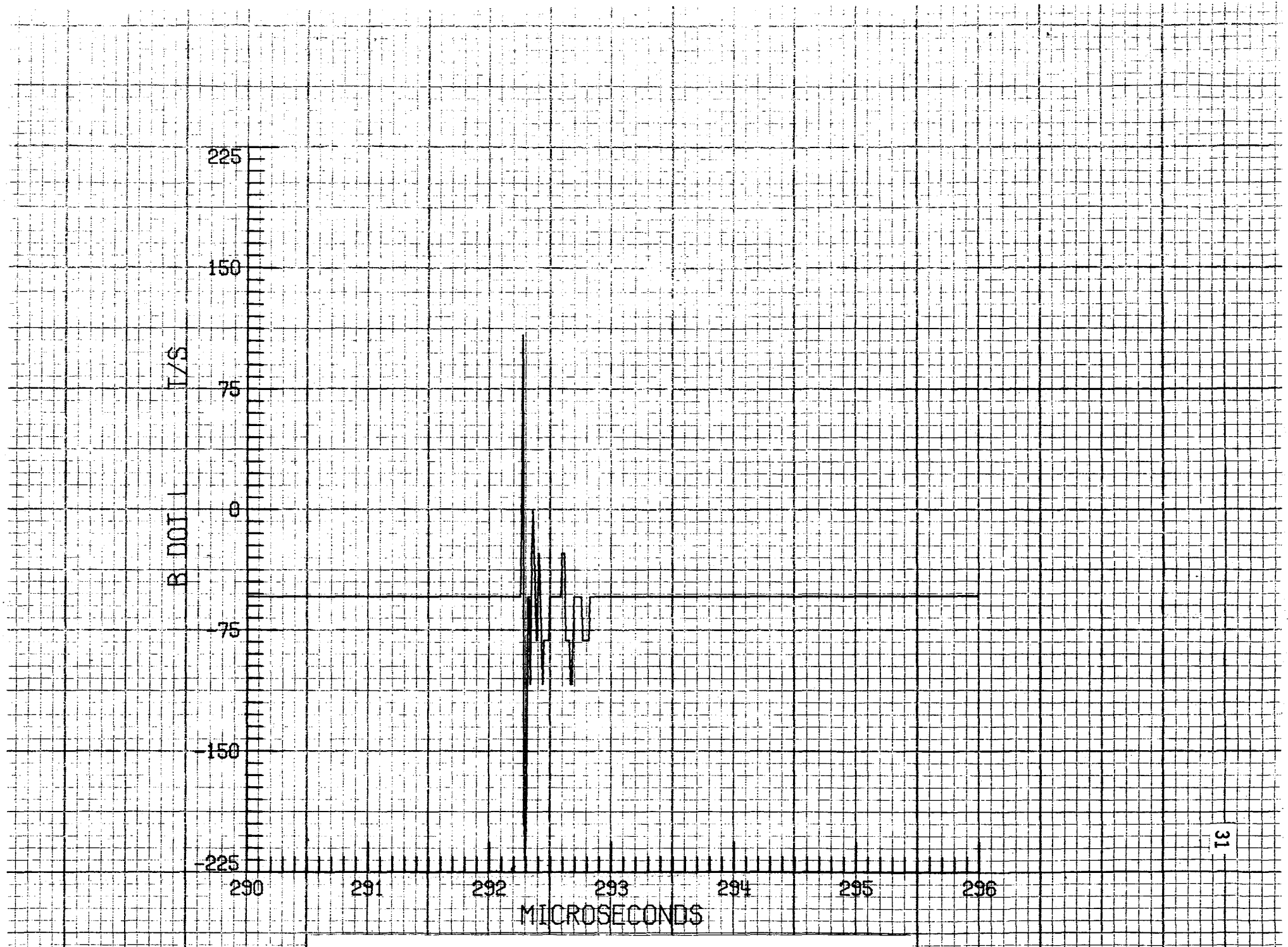

Figure 24. - B-dot sensor - flight 80-038, record 3.

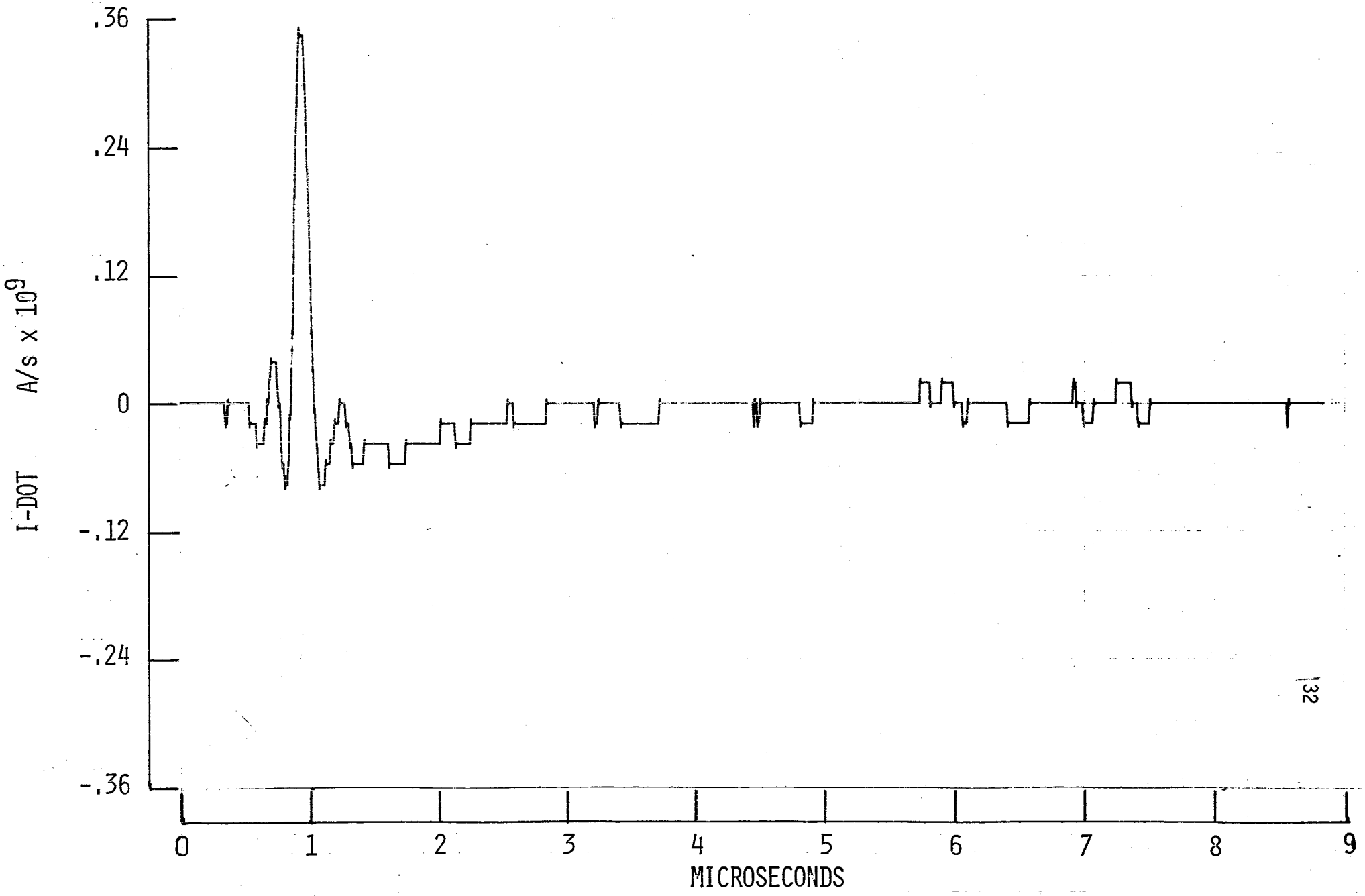

Figure 25. - I-dot sensor - flight 80-038, record 3.

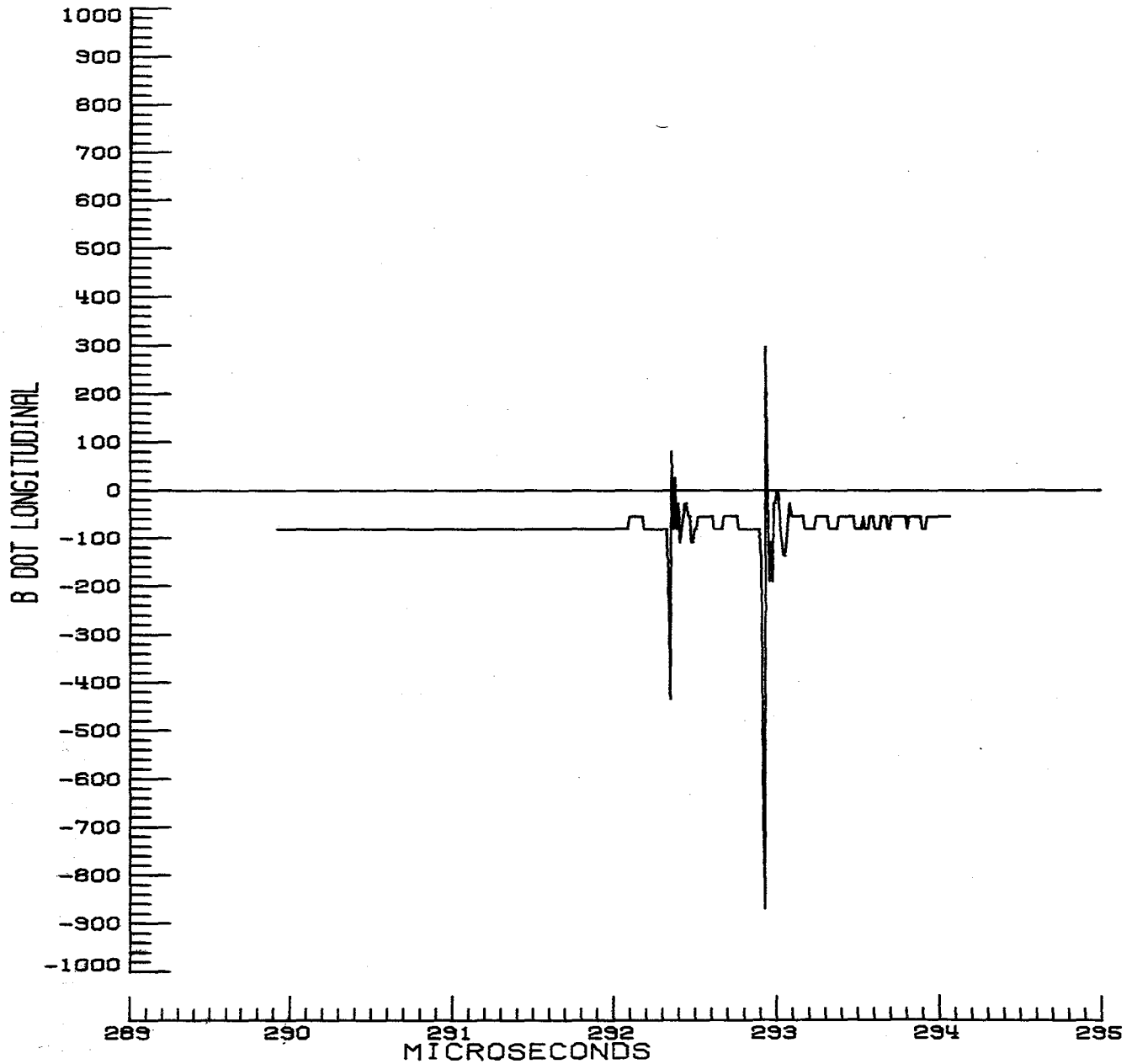

Figure 26. - B-dot sensor - flight 80-038, record 4.

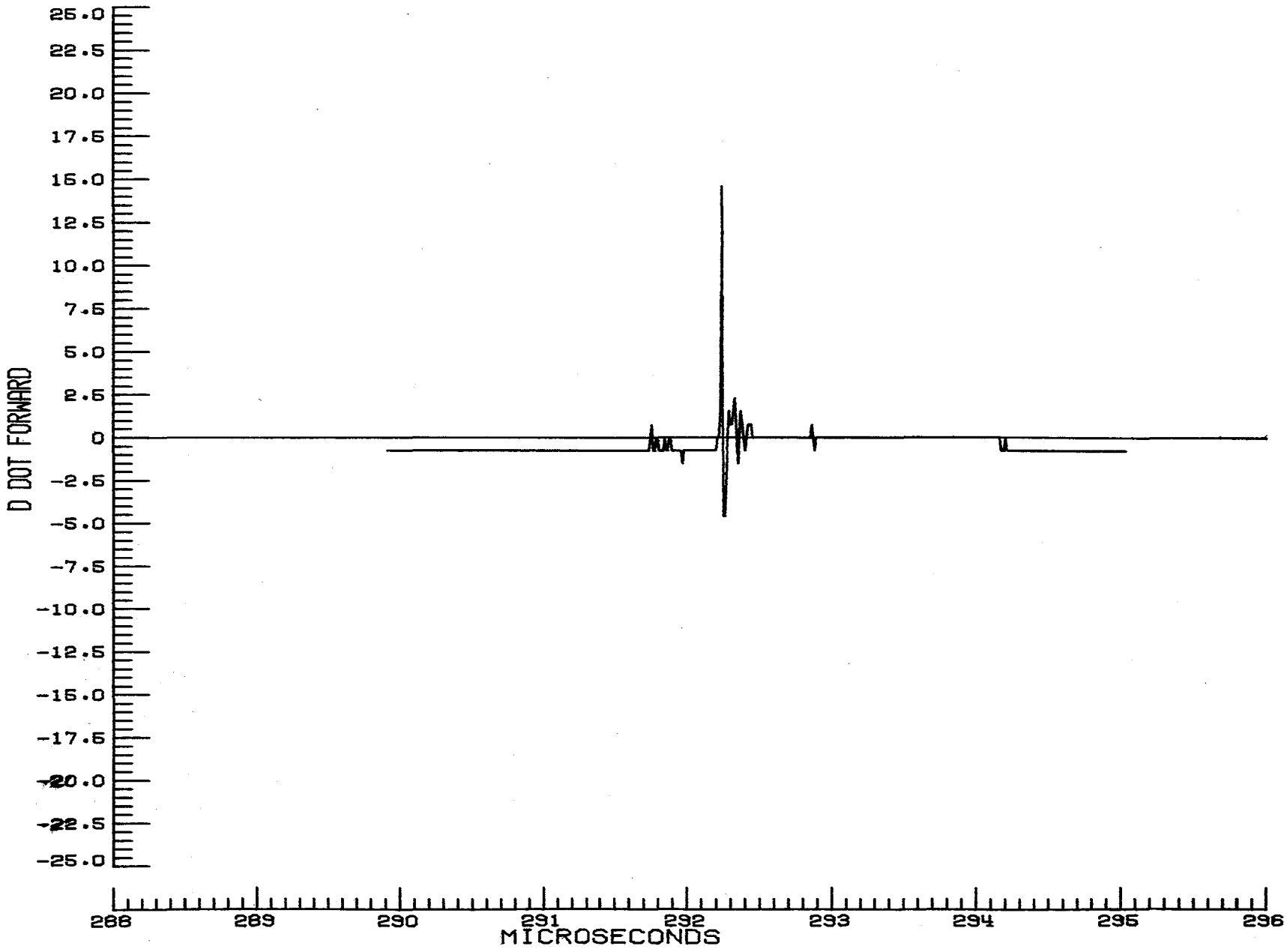

Figure 27. - D-dot sensor - flight 80-038, record 4.

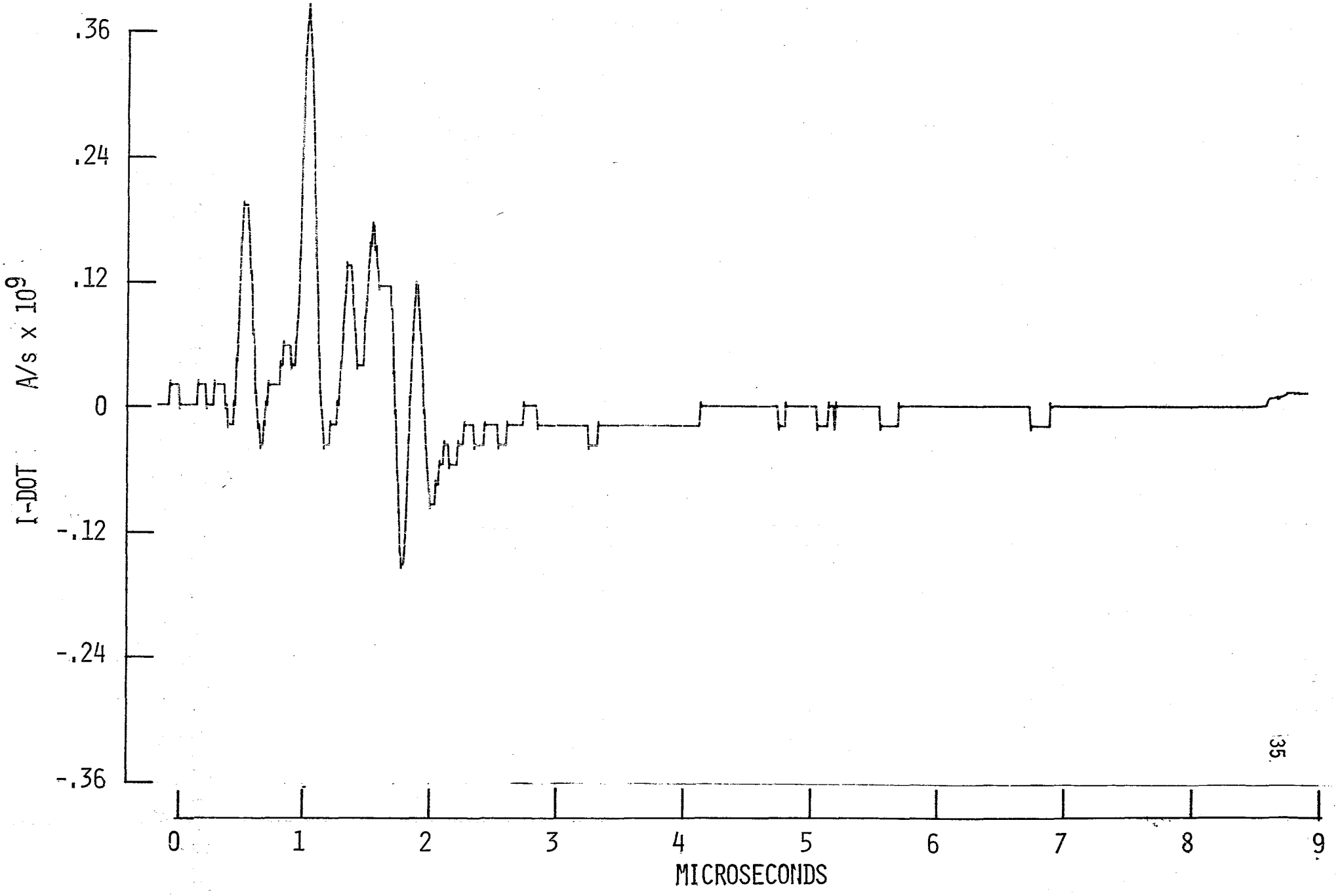

Figure 28. - I-dot sensor - flight 80-038, record 4.

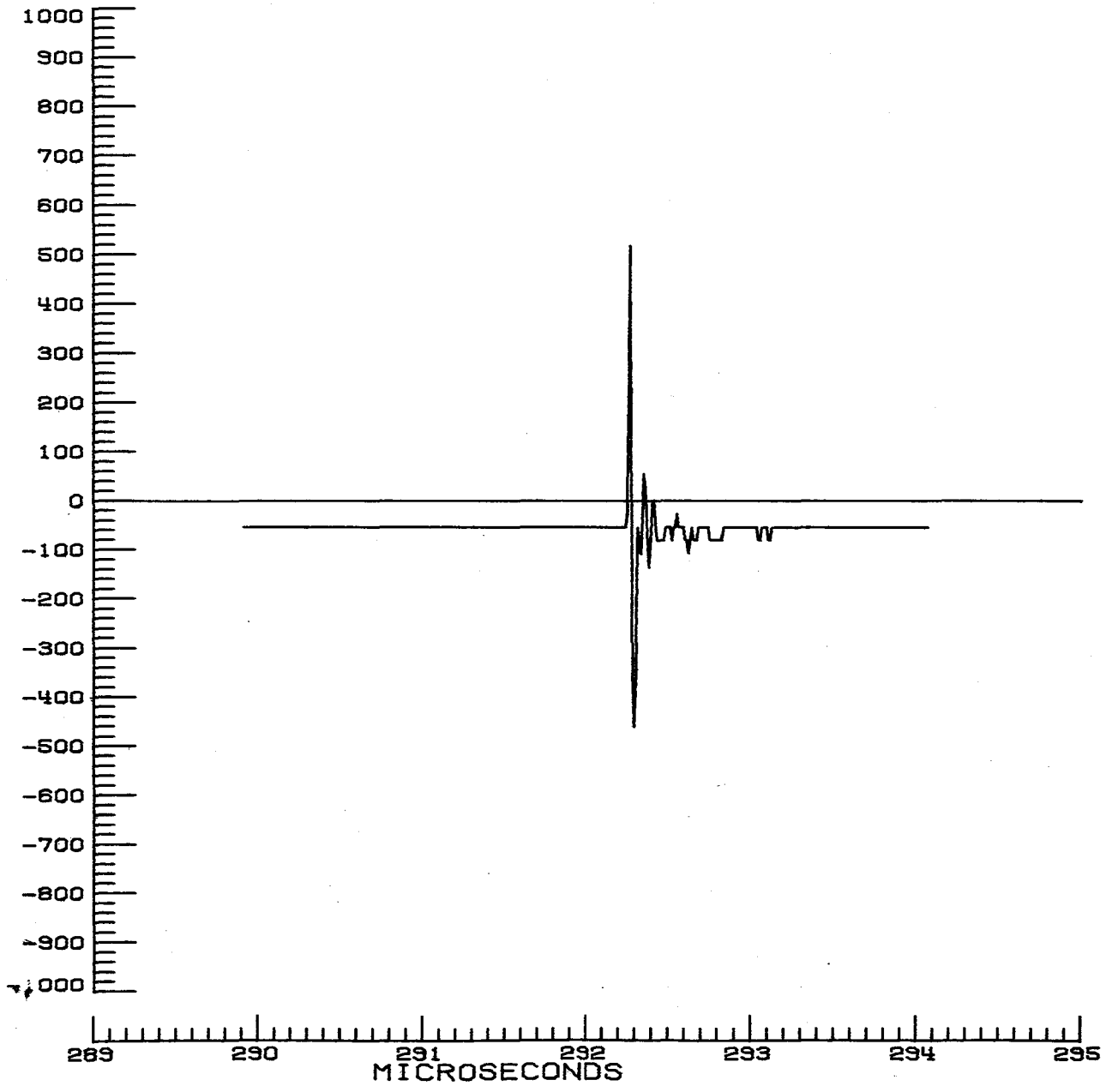

Figure 29. - B-dot sensor - flight 80-038, record 5.

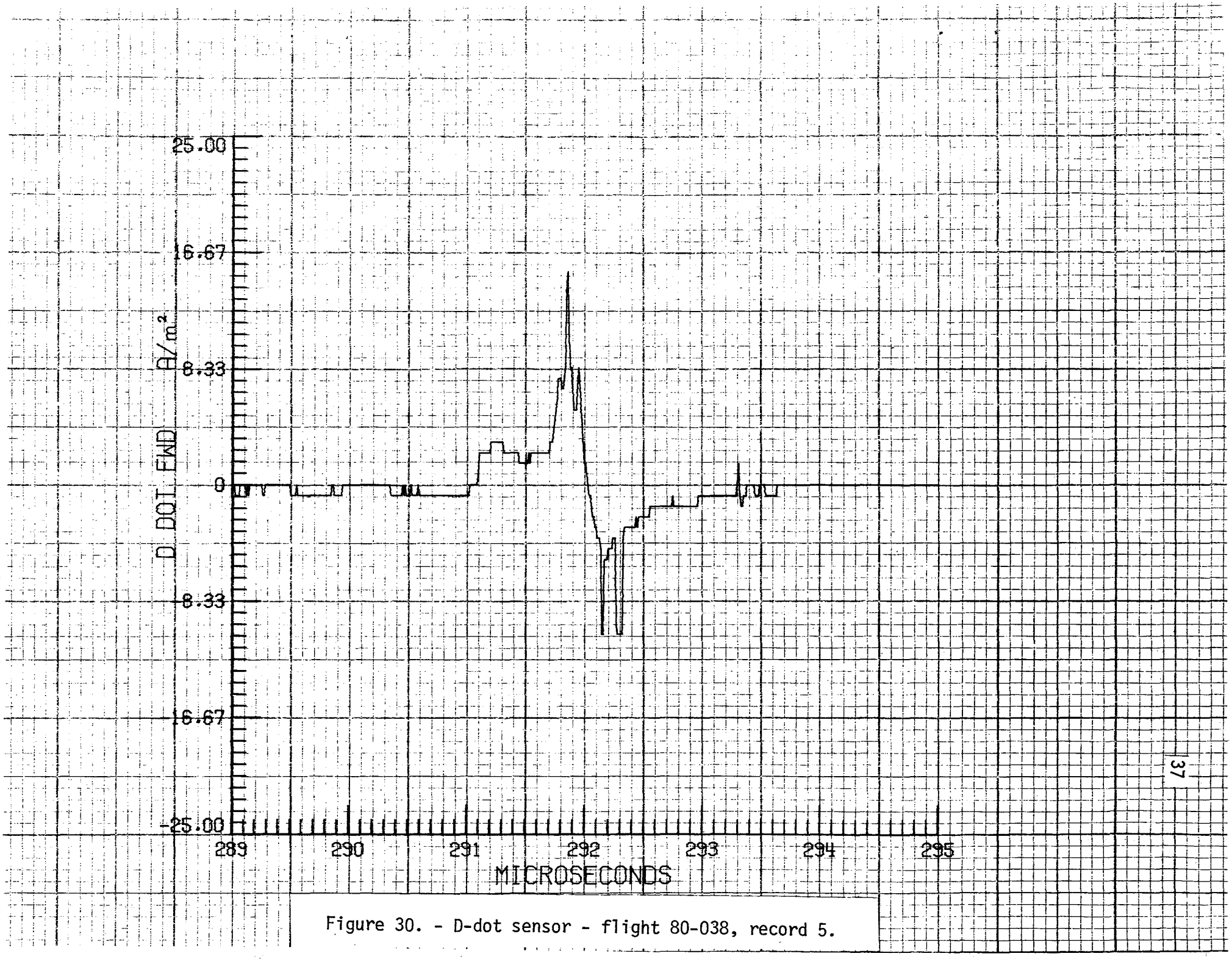

Figure 30. - D-dot sensor - flight 80-038, record 5.

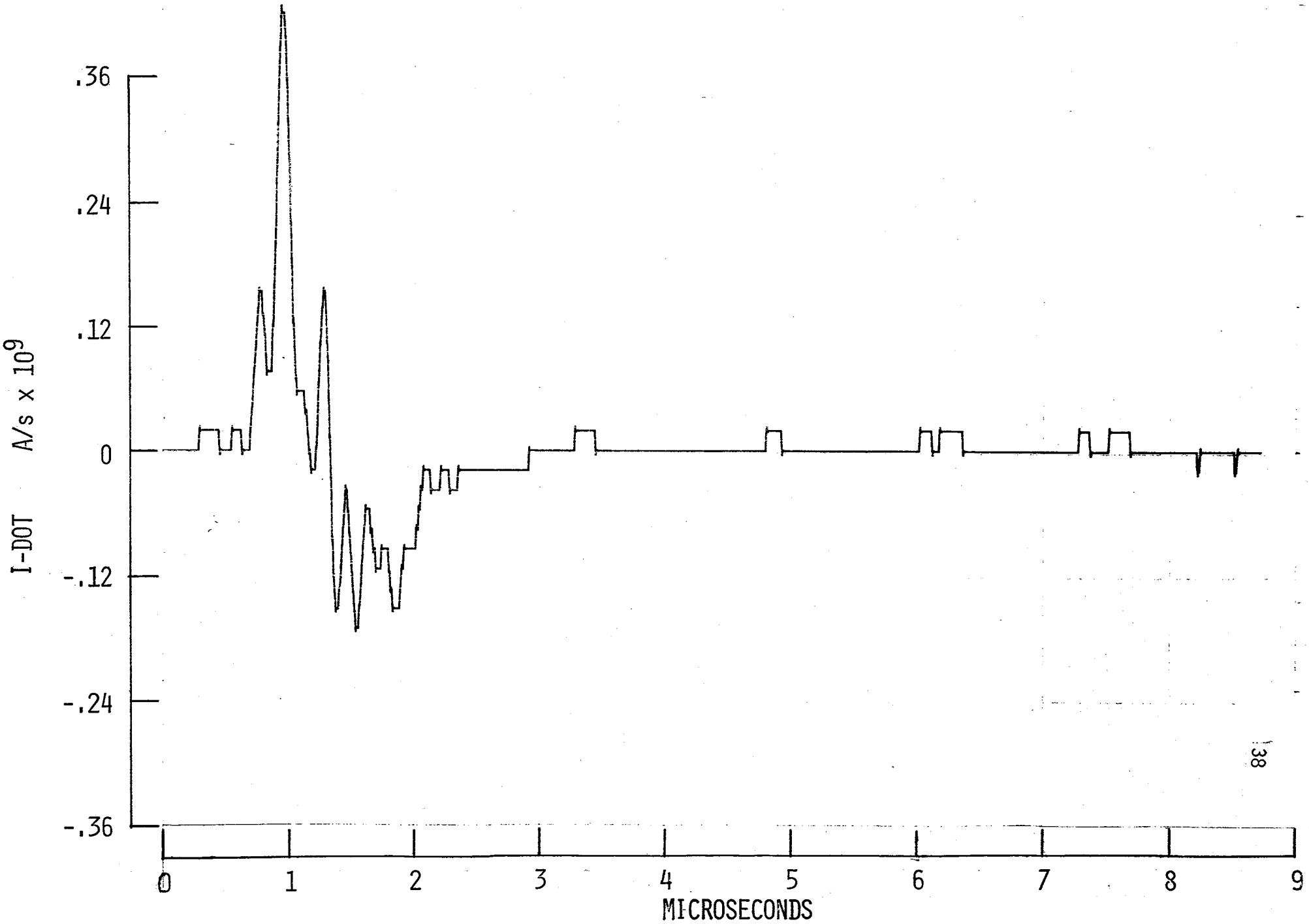

Figure 31. - I-dot sensor - flight 80-038, record 5.

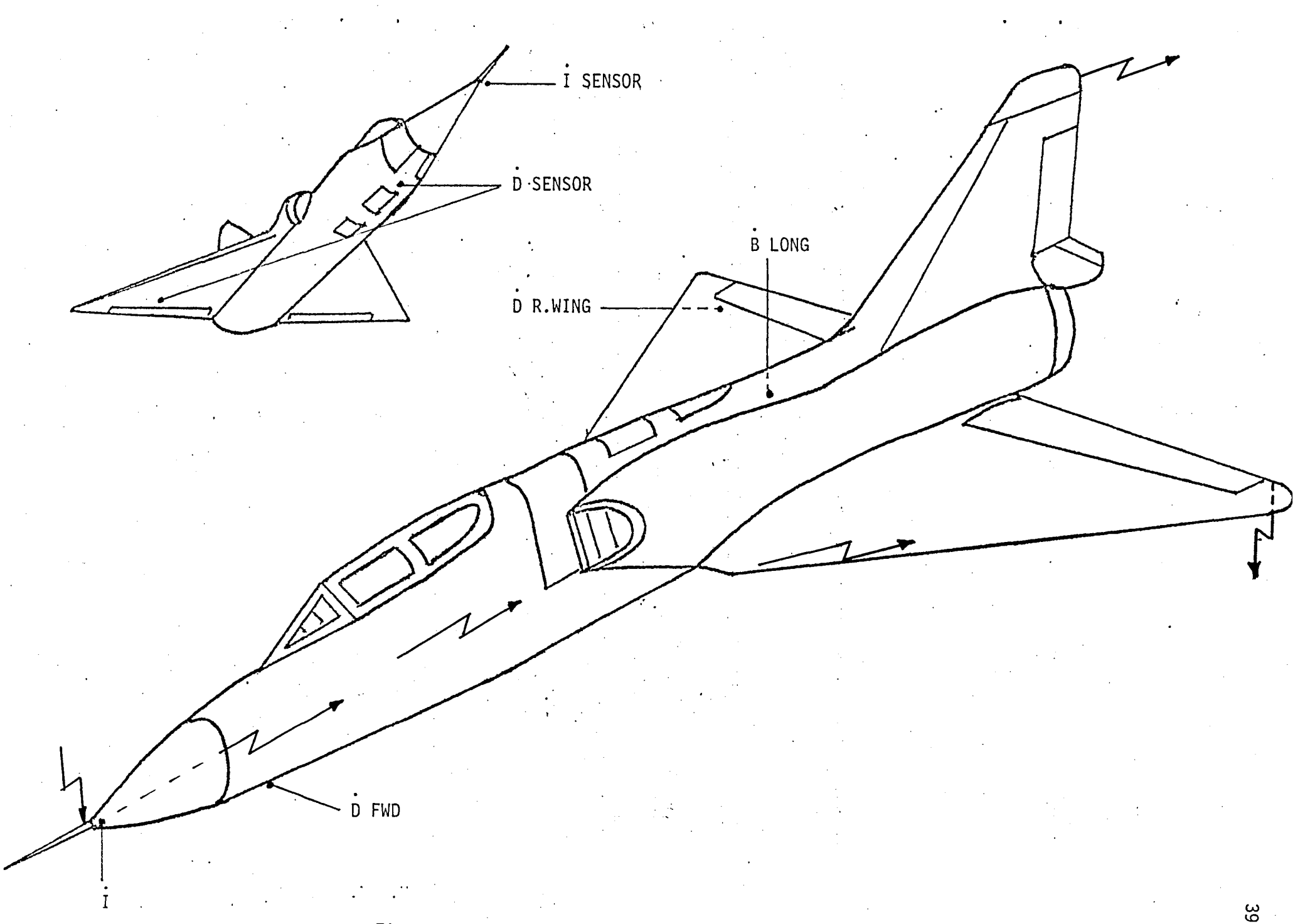

Figure 32. - Strike attachment path for flight 80-018.

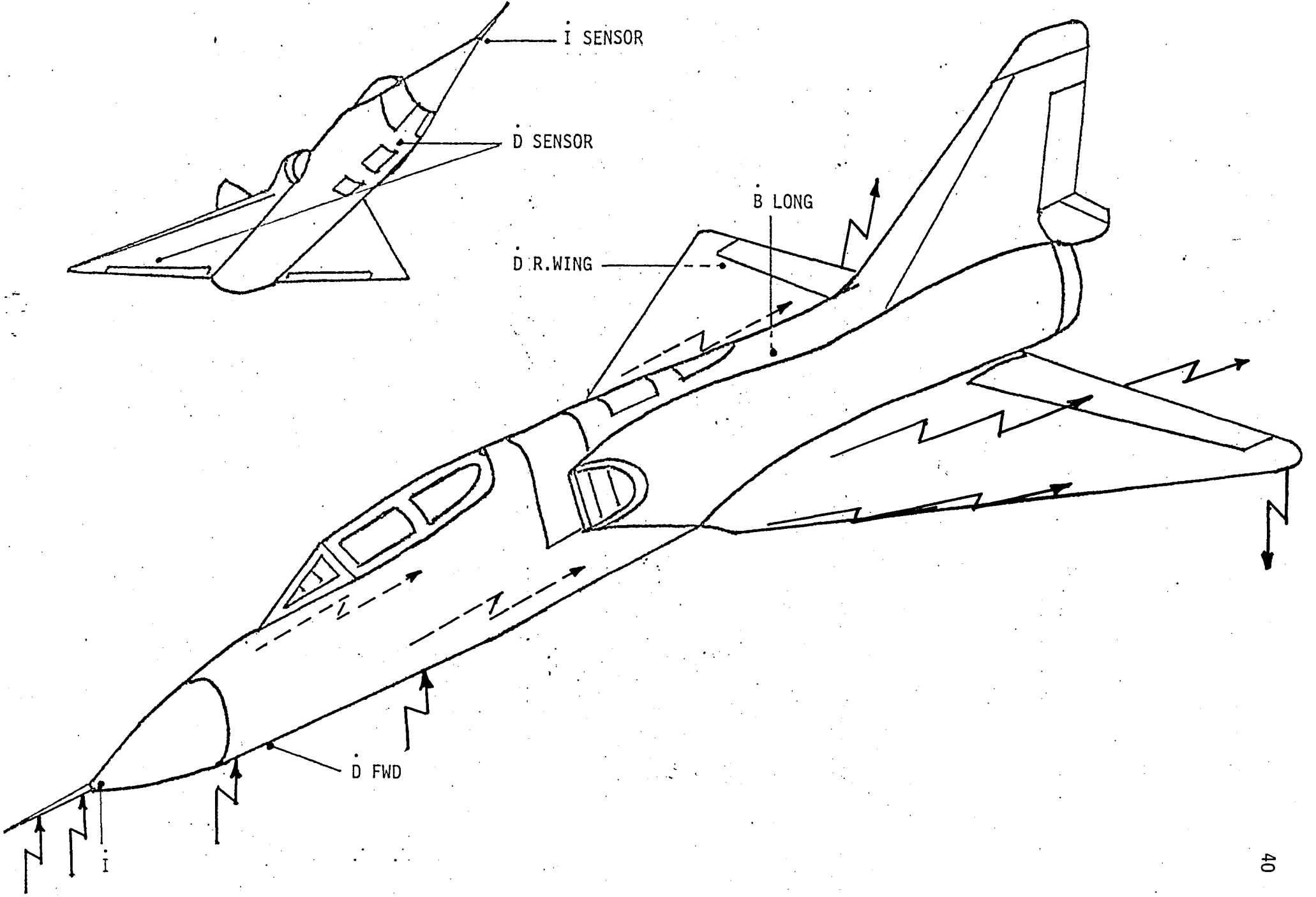

Figure 33. - Strike attachment path for flight 80-019.

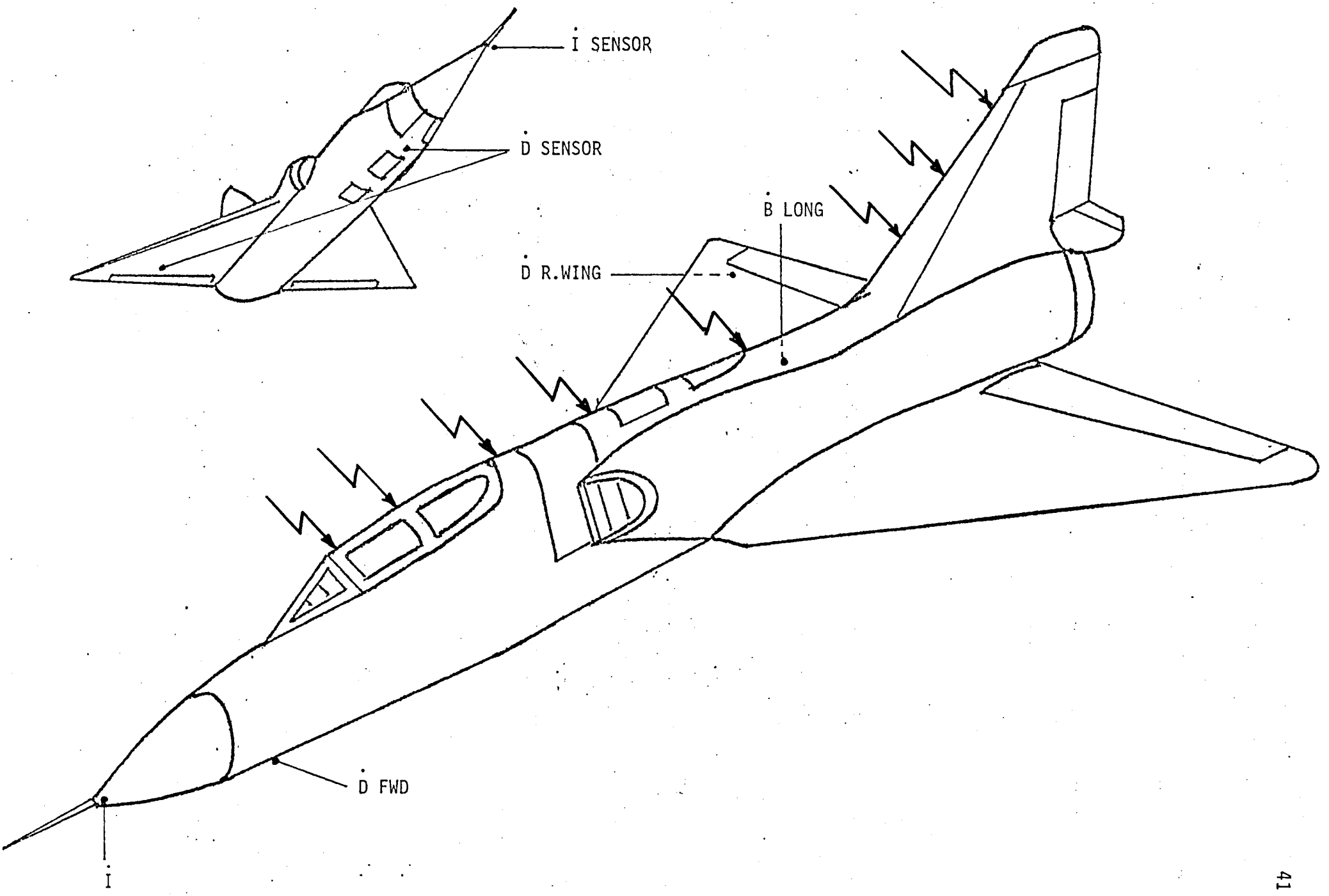

Figure 34. - Strike attachment path for flight 80-029.

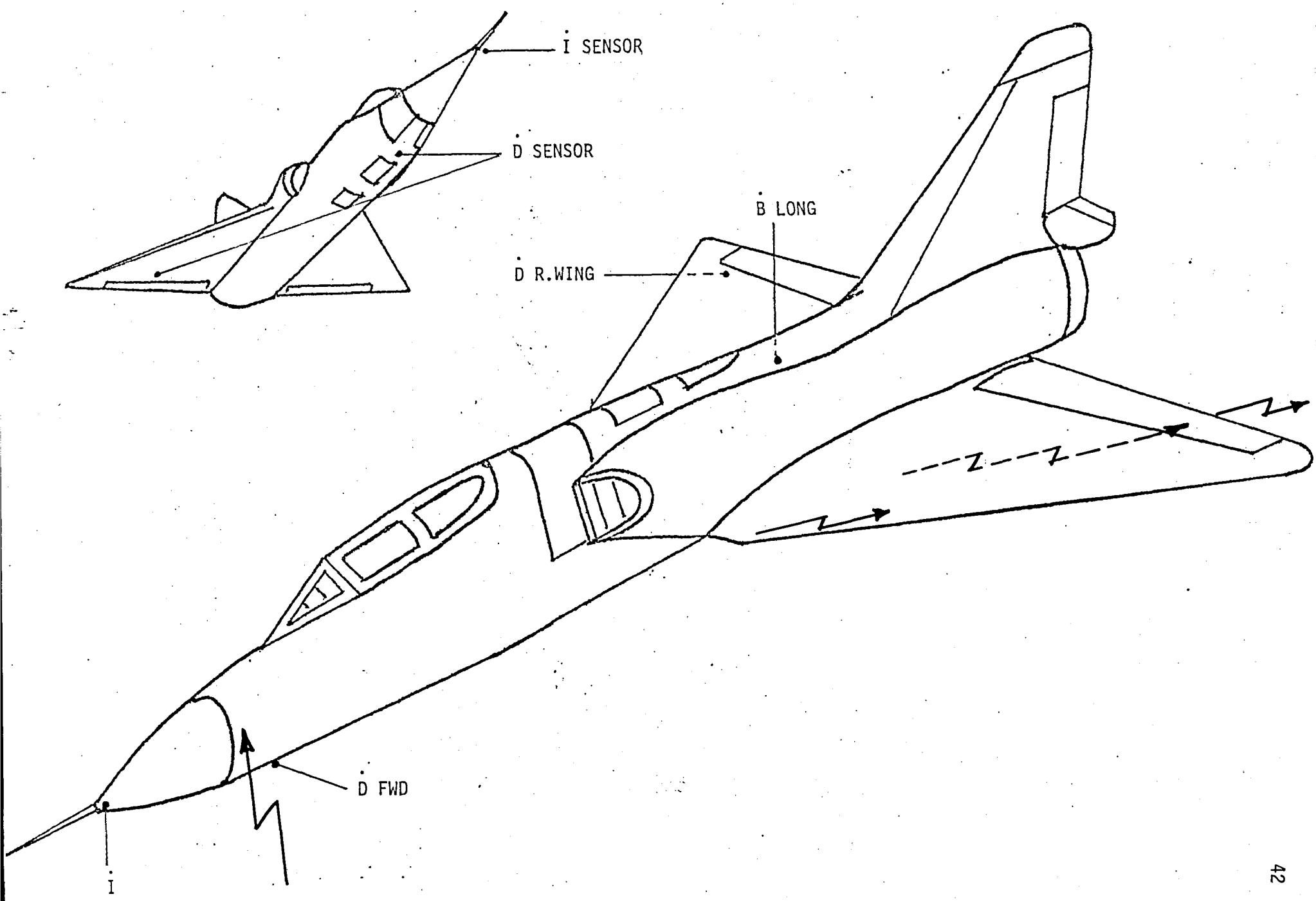

Figure 35. - Strike attachment path for flight 80-036.

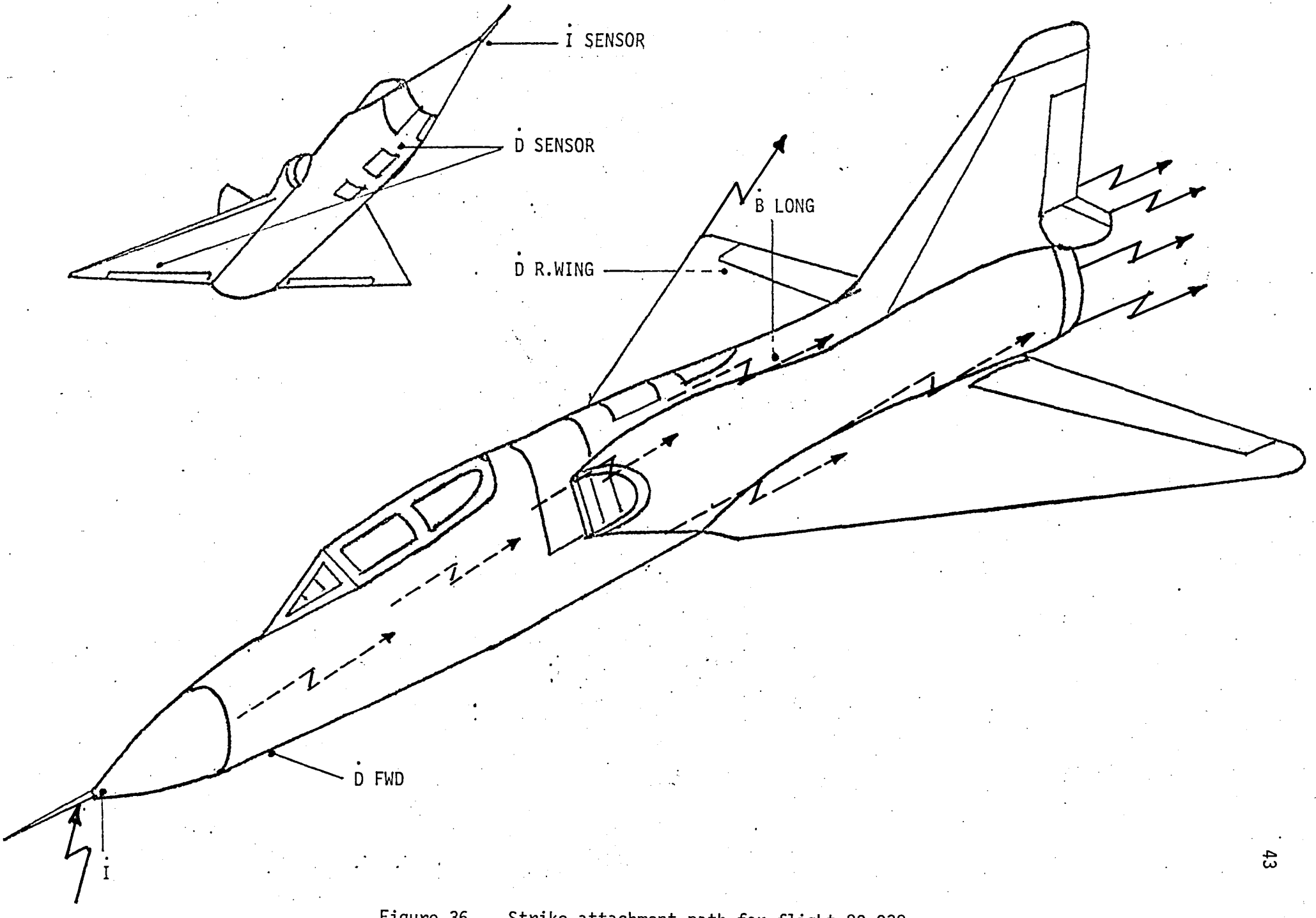

Figure 36. - Strike attachment path for flight 80-038.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-81946		

4. Title and Subtitle	5. Report Date
1980 Direct Strike Lightning Data	February 1981
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Felix L. Pitts and Mitchel E. Thomas	
9. Performing Organization Name and Address	10. Work Unit No. 505-44-13-02
NASA Langley Research Center Hampton, VA 23665	11. Contract or Grant No.
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
National Aeronautics and Space Administration Washington, DC 20546	Technical Memorandum
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Data waveforms are presented which were obtained during the 1980 direct-strike lightning tests utilizing the NASA F-106B aircraft specially instrumented for lightning electromagnetic measurements. The aircraft was operated in a thunderstorm environment to elicit strikes in the vicinities of the National Severe Storms Laboratory, Norman, Oklahoma, and the NASA Langley Research Center, Hampton, Virginia. Concurrently recorded electric and magnetic field and lightning current data were obtained.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Lightning Direct-strike lightning Electromagnetic measurement	Unclassified - Unlimited Subject Category 47

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
UNCLASSIFIED	UNCLASSIFIED	43	A03

For sale by the National Technical Information Service, Springfield, Virginia 22161